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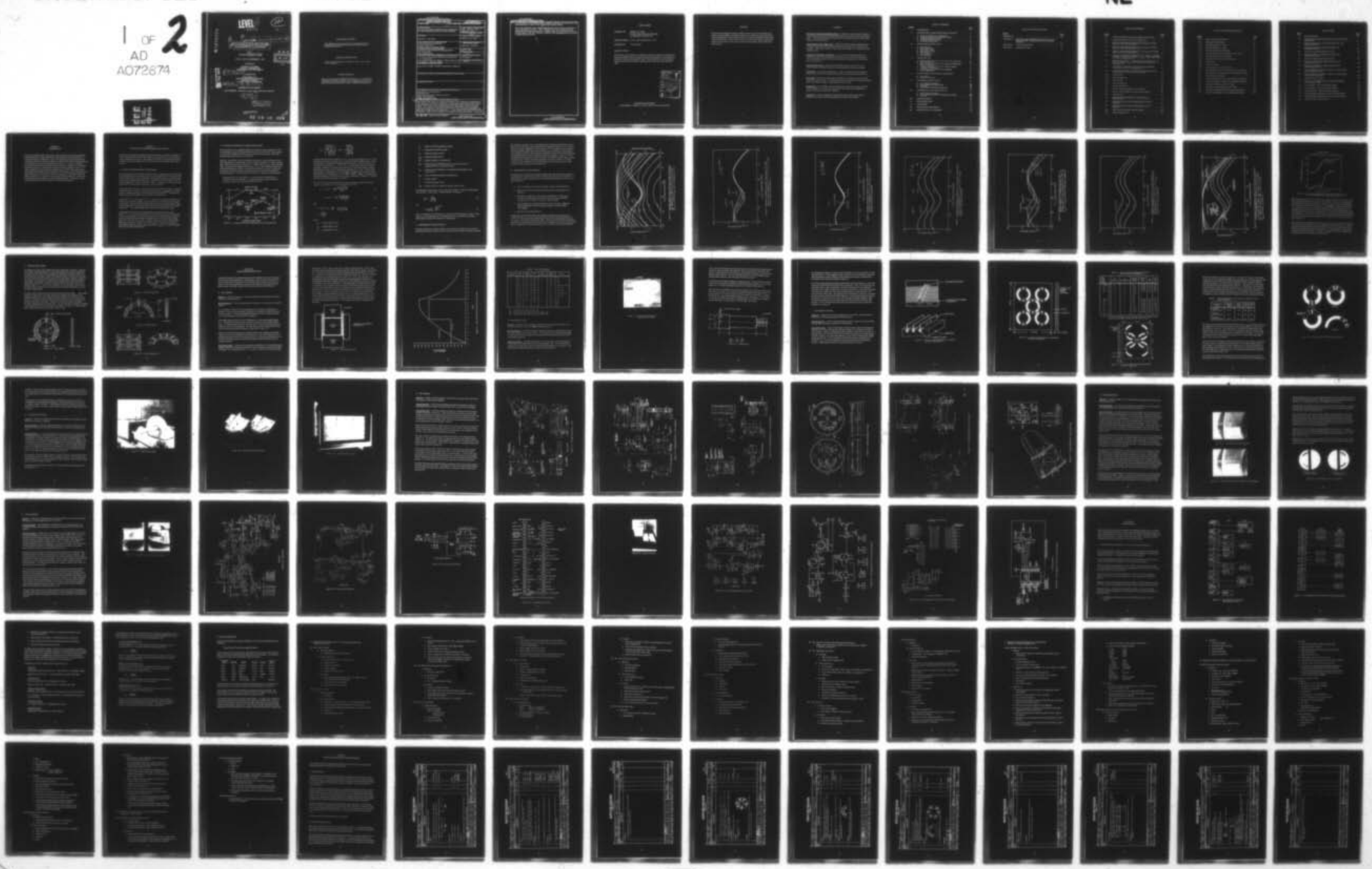

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(9) FINAL REPORT. 14 Jul 75-14 Dec 78,

(6) PRODUCTION ENGINEERING MEASURE (PEM) MANUFACTURING METHODS AND TECHNOLOGY FOR PIEZOELECTRIC TRANSFORMERS.

(15) CONTRACT DAAB07-76-C-0008

JULY 14, 1975 TO DECEMBER 14, 1978

PLACED BY:

TECHNICAL SUPPORT
ACTIVITY, USAERADCOM
FORT MONMOUTH, NEW JERSEY

(11) 15 May 79

CONTRACTOR

HONEYWELL INC.
DEFENSE ELECTRONICS DIVISION
CERAMICS CENTER
GOLDEN VALLEY, MINNESOTA

(10) William B. Harrison

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MANUFACTURING METHODS AND TECHNOLOGY FOR PIEZOELECTRIC TRANSFORMERS		5. TYPE OF REPORT & PERIOD COVERED Final - July 14, 1975 - August 31, 1978
		6. PERFORMING ORG. REPORT NUMBER 47514
7. AUTHOR(s) William B. Harrison		8. CONTRACT OR GRANT NUMBER(s) DAAB07-76-C-0008
9. PERFORMING ORGANIZATION NAME AND ADDRESS Defense Electronics Division Ceramics Center Golden Valley, Minnesota 55422		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project No. 2759525
11. CONTROLLING OFFICE NAME AND ADDRESS Technical Support Activity USAERADCOM Fort Monmouth, New Jersey 07703		12. REPORT DATE May 15, 1979
		13. NUMBER OF PAGES 191
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) U.S. Army Electronics Research and Development Command Army Night Vision and Electro-Optics Laboratory Fort Belvoir, Virginia 22060		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approval for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Piezoelectric transformers; Transformers; Lead zirconate-lead titanate ceramics; Night vision goggles; Image intensifier tubes		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is the final report on Contract DAAB07-76-C-0008, which established a cost-effective production capability for manufacturing piezoelectric ceramic transformers to be used in operating 18mm night vision image intensifier tubes. The 18mm PET production approach established by this program produced acceptable units which met all of the specifications established for this high voltage step-up transformer. A one-element packaged PET was established in place of the original two-element developmental units. This was

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20. accomplished by establishing more realistic resistive and capacitive load requirements for each of the V_{12} and V_3 voltage outputs.

All of the equipment and tooling designed and built produced satisfactory pilot production run units. The cost objectives were achieved on the individual piezoelectric elements. Higher costs were associated with attaching leads to the PET ceramic elements and packaging was more time-consuming than desired.

FINAL REPORT

CONTRACT NO. DAAB07-76-C-0008
Manufacturing Methods and Technology
for Piezoelectric Transformers

PERIOD COVERED: July 14, 1975 to December 14, 1978

PREPARED BY: W. B. Harrison

OBJECT OF STUDY:

The objective of this contract is to establish a production capability for piezoelectric ceramic transformers with all required manufacturing methods, test procedures and production tooling for high production rates. These transformers are to be used in conjunction with a power supply for operating 18mm night vision image intensifier tubes.

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PURPOSE

This Production Engineering Measure (PEM) contract covers all of the tooling, test methods, package designs, mounting techniques, interconnection techniques and other manufacturing methods and techniques required for eventual production of 18mm piezoelectric transformers. These units are to be used with a power supply to improve the performance and reduce cost for image intensifier tubes used in various 18mm night vision devices.

GLOSSARY

Piezoelectric (Ceramic) Transformer (PET). A dielectric ceramic material capable of converting electrical energy into mechanical vibration, and, in turn, back into electrical energy. When properly electroded and polarized, such materials may be used for high-voltage, step-up transformers.

Image Intensifier Tube (Goggle Tube). A binocular system originally designed for use in helmet-mounted night vision light amplification systems which have the appearance of goggles. This system requires a high-voltage power supply which operates from low-voltage batteries.

Piezoelectric Constants or Parameters. A set of electrical parameters which are constants for a particular composition of material that can be used to determine the electro-mechanical, dielectric and elastic properties of a piezoelectric ceramic material (see Section I B).

Hot-Pressed Ceramics. A process for densifying ceramic material to very near theoretical density whereby the material is simultaneously heated under pressure.

Polarization. The process of applying d.c. voltage to a dielectric ceramic element, which orients its dielectric domains and makes the material piezoelectrically active.

Electroding. The process used to apply "metallization" (commonly silver) to specific areas on the ceramic shape. The "metallized" areas are used both for poling the ceramic and for electrically driving or voltage pick-up in the final PET.

Package Case. A thin-walled, injection-molded plastic shell used to enclose the PET ceramic elements. The case also contains electrical terminals and conductors for access to the internal piezoelectric elements.

K-9 PZ-PT. A specific temperature-stable, lead zirconate-lead titanate material produced by Honeywell containing manganese and strontium oxide dopants.

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SECTION I
INTRODUCTION

The narrative and data parts of this report, which describe the production engineering methods developed to produce piezoelectric high-voltage step-up transformers, are covered in Sections II through VIII. Section II describes the analytical approach used to design a piezoelectric (ceramic) transformer (PET) and the impact of various material and configuration variations on performance of this device. Section III reviews the process improvement efforts conducted during the program, and Section IV reviews the manufacturing process, equipment and tooling which were established. Section V reviews the specification and inspection procedures used, Section VI describes results of the engineering samples produced, and Section VII reviews results of the confirmatory samples and pilot run. Section VIII consists of a summary of each process operation, yield and standard hours required for each operation during the pilot run. Direct cost of these operations is furnished as a nondistributable appendix. Conclusions, recommendations and other details are contained in Sections IX through XII.

SECTION II
PIEZOELECTRIC TRANSFORMER DESIGN APPROACH

This section describes the analytical aspects of piezoelectric transformers (PETS), the theory of their operation and how their performance is impacted by materials and geometric configuration variations. The designs of two PETS are then described which are intended for the power supplies used for 18 and 25mm image intensifier night vision devices.

A. REVIEW OF PIEZOELECTRIC TRANSFORMERS

The use of piezoelectric materials for the electrical to mechanical to electrical transfer of energy between two electrical circuits was proposed by Cady[1] as early as 1928, but this concept did not receive significant attention until piezoelectric ceramic barium titanate was developed about 20 years later. Rosen[2] was granted a patent in 1958 on a barium titanate piezoelectric transformer (PET). An analysis of a PET was carried out by Katz[3], who limited his discussions to barium titanate.

The advent of many types of lead zirconate-lead titanate (PZ-PT) ceramics in 1955-1961 brought forward a new family of materials that had greater high temperature stability and power handling capability. New designs have been proposed[4-6], which are now being proven as power supplies for many practical considerations.

Honeywell[9, 10], as well as others[7, 8], has pursued the development of PETS for the Night Vision Scope Power Supply. In these instances it was apparent that the normal commercially available PZ-PT materials could not be used in a single element design to achieve the desired performance characteristics within the space and drive voltage limitations[9]. This is particularly true in the -25 ± 40°F temperature region.

An approach to overcoming these difficulties has been demonstrated in recent studies.[11, 12] In these efforts modification of the PZ-PT composition was developed which was less sensitive to environmental temperature changes and of such quality to make a packaged PET with two washer-shaped elements to meet the output voltages required for the 18mm power supply. It was also shown that the drive voltage of the PET can be increased to at least 5 volts peak-to-peak. The specific composition developed was $Pb_{0.94}Sr_{0.06}(Zr_{0.53}Ti_{0.47})_{0.99625}Mn_{0.005}O_3$. It is this composition which is being used in this program.

B. ANALYTICAL APPROACH TO TRANSFORMER DESIGN

The process involved in designed piezoelectric elements for use as piezoelectric transformers (PETs) has been reviewed thoroughly by Harrison and Bonne.[9] Math modeling of various PET configurations was shown to be feasible so that computerized design and operating characteristics can be predicted.

Similarly, the influence of various changes in piezoelectric material parameters has been described and a trend analysis made for variations in dielectric constant, electrode area, mechanical quality (Q_m), piezoelectric voltage coefficient (q_{33}), Young's Modulus (Y_3^E), and piezoelectric coupling coefficient k_{33}. Thus, a well-established math model has been developed and proven for many types of piezoelectric ceramic transformers. This model can predict transformer performance for any of the many piezoelectric materials produced. The process required to arrive at a transformer design follows:

The output power, P_s, and efficiency, η, of a piezoelectric transformer as a function of the load resistance, R_L, typically behaves as shown in Figure 2-1, which in turn can be described by functions of the form:

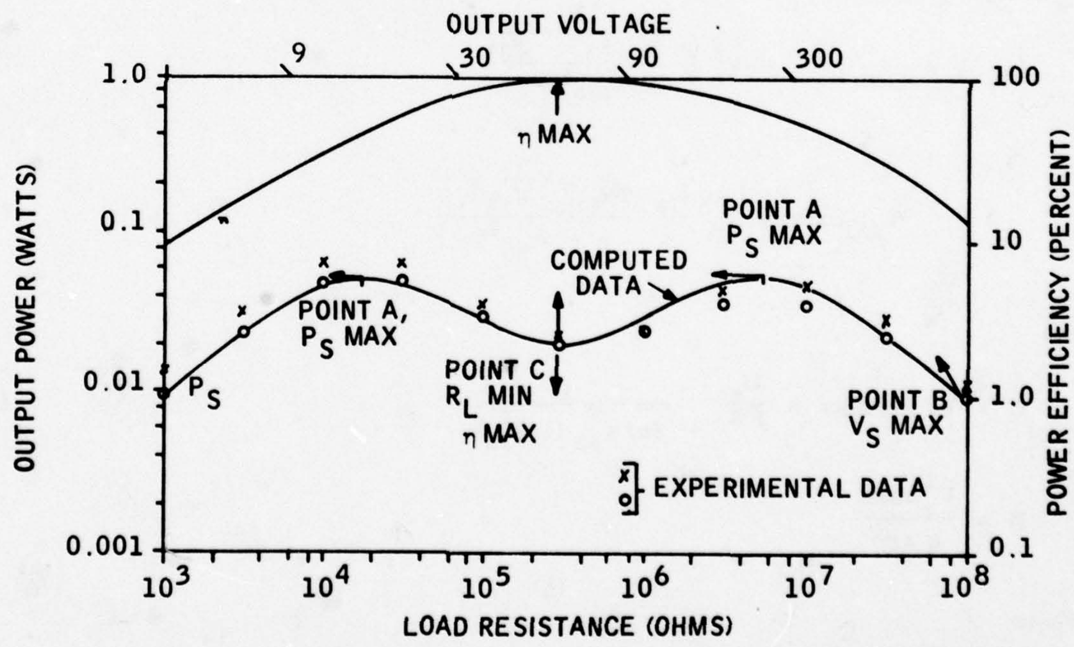


Figure 2-1. Comparison Between Computed and Experimental PET Data

$$P_s = \frac{A\left(\dfrac{8BC^2R_L}{R_L^2 + C^2}\right)}{\left(1 + \dfrac{2BC^2R_L}{R_L^2 + C^2}\right)^2} \quad \text{and } \eta = \frac{\dfrac{2BC^2R_L}{R_L^{\,2} + C^2}}{1 + \dfrac{2BC^2R_L}{R_L^2 + C^2}} \tag{1}$$

The power function has two maxima if $B > 1/C$, but only one maximum if $B \leq 1/C$. The two maxima are located at values of R_L for which the quantities $8BC^2R_L/R_L2 + C^2$ and the denominator of equation (1) simultaneously become unity. In the case of $B > 1/C$, a minimum is located at $R_L = C$. Also, at $R_L = C$ the efficiency function has only one maximum. Therefore, C represents the value of R_L at the power minimum, which is identical with the value of R_L at the maximum efficiency (R_L, η max). The maximum power peaks are represented by A (P_s max) and the maximum output voltage (V_s max) under open-circuit conditions ($R_L \rightarrow \infty$) = $C\sqrt{8AB} = \sqrt{P_sR_L}$. Equation (1) indicates that the characterization of each P_s-versus-R_L curve, such as given in Figure 2-1, requires definition of only three parameters, A, B and C.

In terms of the involved physical dimensions and piezoelectric constants of the PET, P_s max, V_s max and R_L or η max can be written in the form:

$$A = P_s, \text{ max} = V_p^2 \frac{W}{T} \frac{Q_m Y_3^{E\,3/2} d_{31}^2}{2\pi\rho^{1/2}} \tag{2}$$

$$V_s, \text{ max} = V_p \frac{L_s}{T} \frac{4Q_m Y_3^E g_{33} d_{31}}{\pi^2(1-k_{33}^{\,2})} \tag{3}$$

and

$$C = R_L, \eta \text{ max} = \frac{L_s}{TW} \quad \frac{1}{2\pi f \epsilon_{33}^T (1-k_{33}^2)} \tag{4}$$

$$B = \frac{V_s^2 \text{ max}}{8\ AC^2}$$

where

V_s = output voltage in volts

V_p = input voltage in volts

P_s = output power in watts

L_s = length of the PET-secondary in meters

T = Thickness of the PET in meters

W = width of the PET in meters

Q_m = mechanical quality factor

Y_3^E = Young's modulus in newton/meters^2

g_{33} = induced electric field/applied stress, both in the direction of polarization (DP), in volt meters/newton

d_{31} = induced strain (perpendicular to DP)/applied field (parallel to DP) in meters/volt

k_{33} = electromechanical longitudinal coupling factor

ρ = density in kg/m^3

f = resonant frequency in Hertz

ϵ_{33}^T = absolute dielectric constant at constant stress, in F/m

The independent measurement of a few of the above constants, together with the parameters P_s max, V_s max and R_L, η max and the general relations

$$(k_{33})^2 = \frac{\epsilon_{33}^T}{g_{33}^2 \, Y_{33}^E} \tag{5}$$

and

$$f = \frac{n}{2(L_s+L_p)} \left(\frac{Y_3^E}{\rho}\right)^{1/2} \tag{6}$$

with n = vibrational mode number and L_p = length of the PET-primary in meters, represents one way of obtaining an exact determination of all the piezoelectric constants influencing performance of a piezoelectric transformer.

C. PERFORMANCE CHARACTERISTICS

The above relations are essential tools for any materials or design study, not only for evaluating and ranking materials but also to point out the directions for optimum tradeoffs.

The influence of changes in the various piezoelectric and geometric parameters used in Equation 2-6 on the output power and efficiency are shown in Figures 2-2 to 2-7 for the curved rectangular configuration shown in Figure 2-8. It is apparent from these figures that the composition and process used to fabricate the ceramic have a strong influence on the behavior of a PET. These intrinsic properties of the material are also influenced by extrinsic parameters such as temperature and drive voltages. In general, most of the piezoelectric parameters are fairly stable with temperature; however, Q_m, mechanical quality factor, drops rapidly with temperature, as shown in Figure 2-9. Figure 2-2 can be used to determine the pronounced decrease in efficiency and power output caused by a change in Q_m from only 1000 to 250.

D. ADVANTAGES OF PET APPROACH

An examination of the night vision image intensifier tube power requirements shows that the piezoelectric transformer approach is a technically sound means of achieving the high-voltage low-power outputs because of the following advantages over the ferrotransformer approach:

- Lower exciting current, which can produce a higher operating efficiency.
- Simpler construction, which allows batch fabrication with significant cost reduction.
- Reduction in complexity, which improves reliability by a simple piezotransformer that eliminates the need for fine wire-wound transformers and may reduce the number of multiplier stages required.
- Thinner shape factor, which will reduce the size of the power supply and should significantly reduce the weight and moment of inertia of night vision goggles.
- Inherent short-circuit protection.

Honeywell has made breakthroughs in developing new modified lead zirconate-lead titanate (PZ-PT) piezoelectric transformers that will maintain high performance over the -54°C to +52°C ambient temperature range. Previous to this Honeywell development, piezoelectric transformers did not meet military low-temperature operation requirements due to a degradation of performance below -10°C, nor did they meet space allocations.

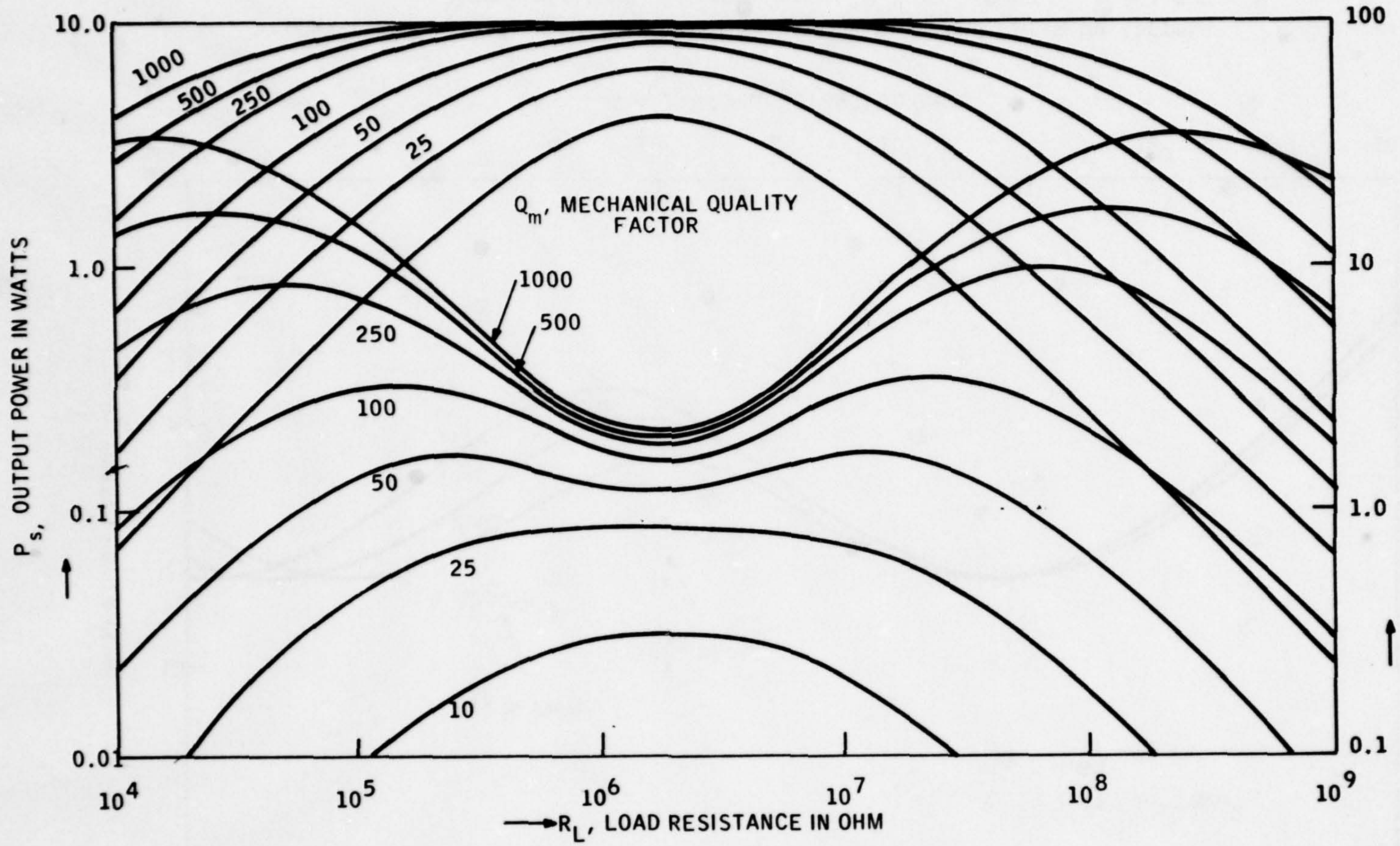


Figure 2-2. Calculated Influence of Q_m on PET Output Power and Efficiency. PET Dimensions in cm 2.54 L x 0.60 W x 0.08 T, f = 63 kHz, $\epsilon_{33} = 1240\ \epsilon_o$, $g_{33} = 0.025$ Vm/N, $d_{31} = 1.1 \times 10^{-10}$ m/V, $Y_3^E = 8.0 \times 10^{10}$ N/m^2, $k_{33} = 0.65$, $\rho = 7600$ Kg/m, Vp = 30 V

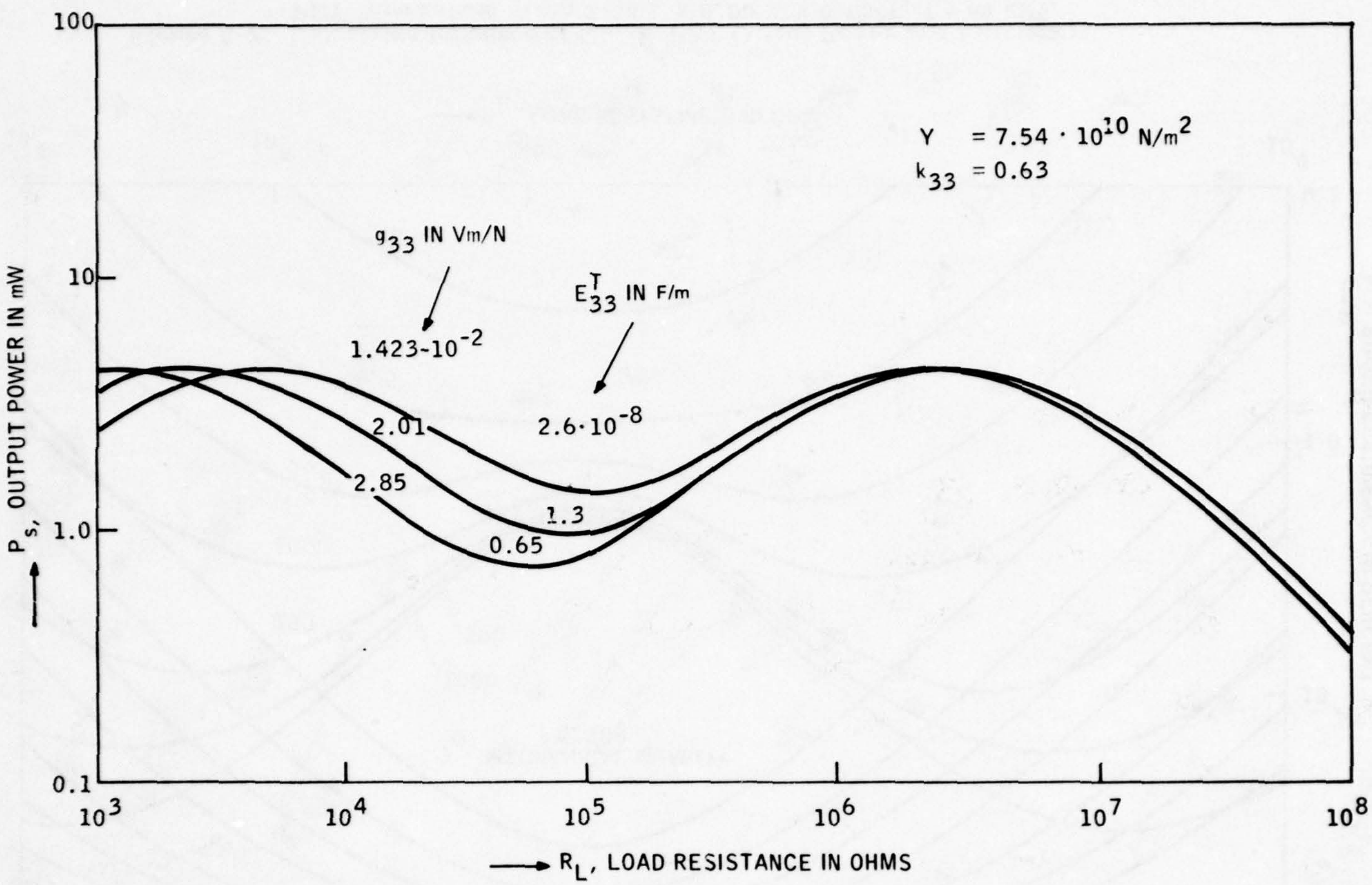


Figure 2-3. Influence of Simultaneous Changes in ϵ^T_{33} and g_{33} on the Output Power of a PET of Configuration "B." $V_p = 0.53\ V_{rms}$ ($= 1.5\ V_{p-p}$), Material: K13 hp, Room Temperature.

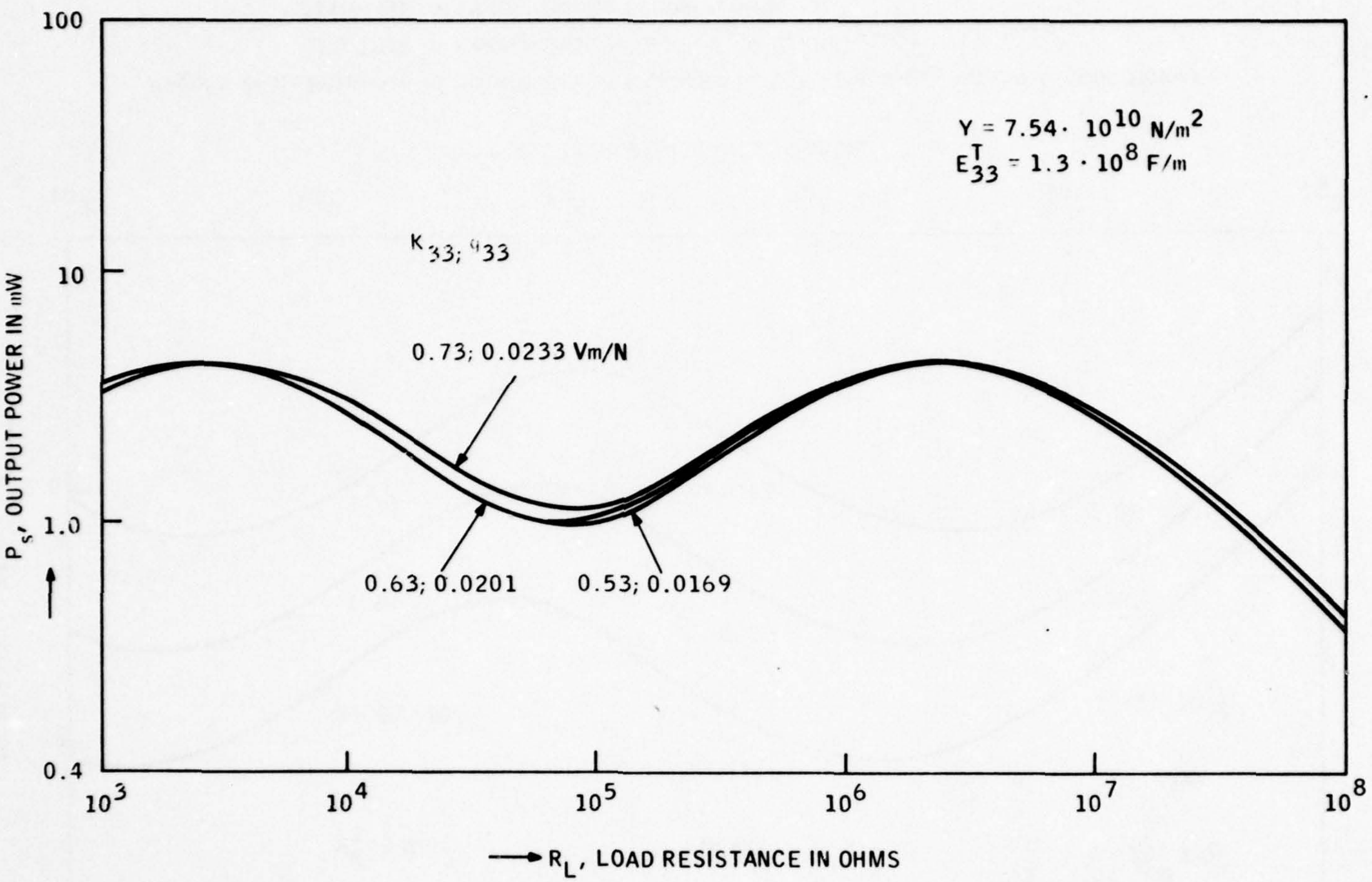


Figure 2-4. Influence of Simultaneous Changes in k_{33} and g_{33} on the Output Power of a PET of Configuration "B." $V_p = 0.53\ V_{rms}$ (= 1.5 V_{p-p}), Material: K13 hp, Room Temperature.

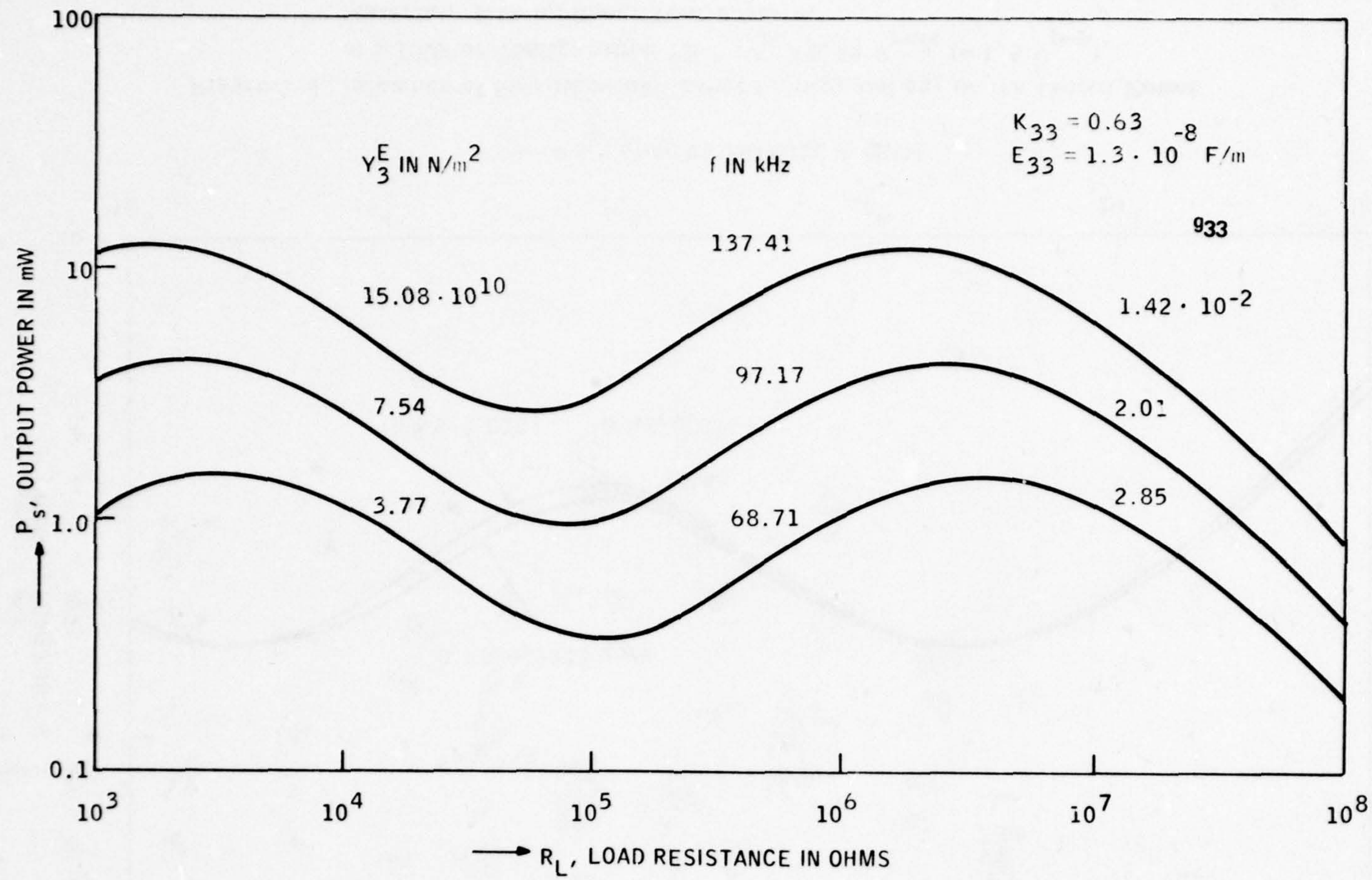


Figure 2-5. Influence of Simultaneous Changes in Y_3^E, f and g_{33} on the Output Power of a PET of Configuration "B." $V_p = 0.53\ V_{rms}$ (= 1.5 V_{p-p}), Material: K13 hp, Room Temperature.

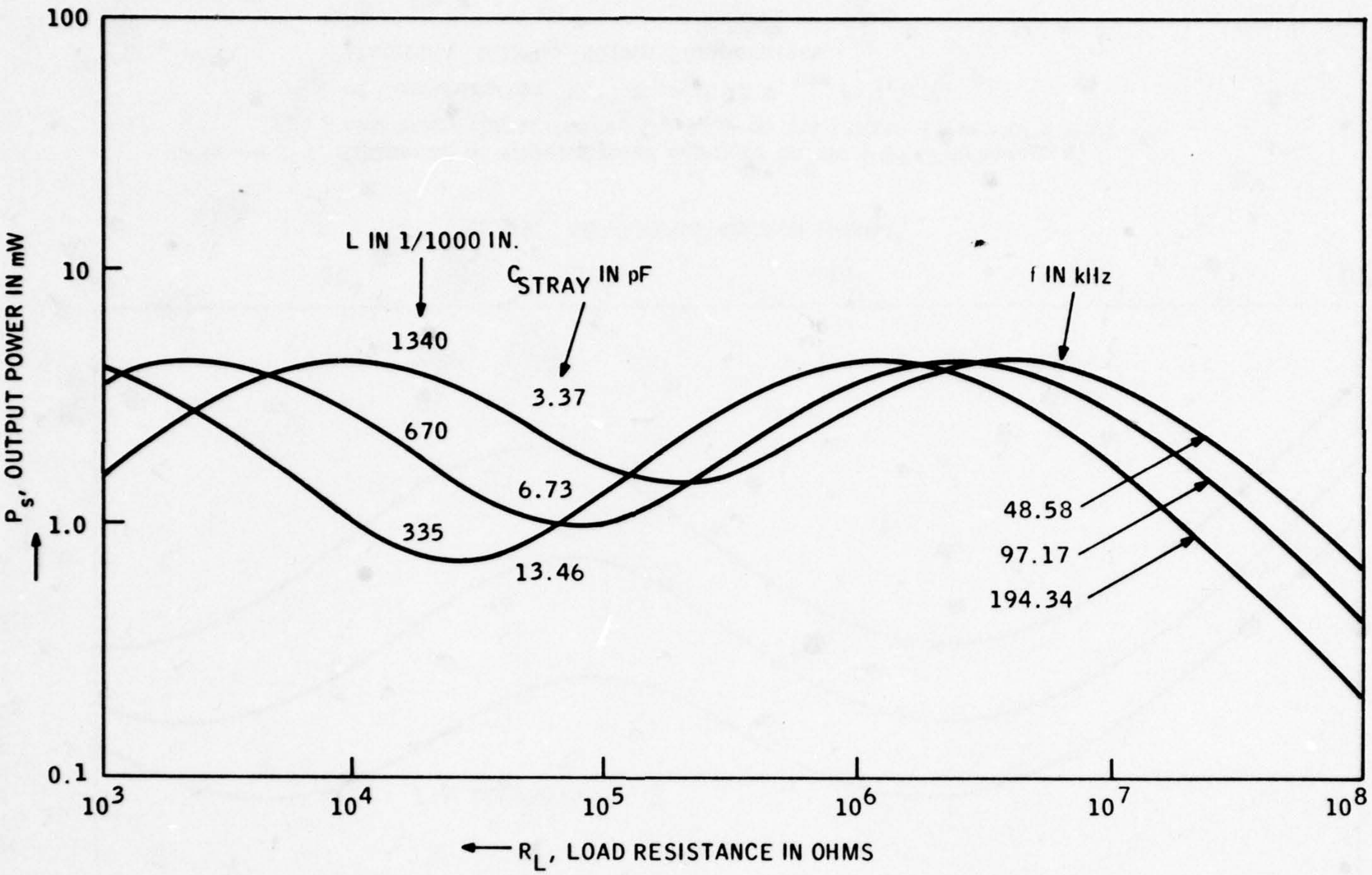


Figure 2-6. Influence of Simultaneous Changes in the PET Length, L, Resonant Frequency, f, and Stray Capacitance, C_{stray}, on the Output Power of a PET of Configuration "B." $V_p = 0.53$ V_{rms} (= 1.5 V_{p-p}), Material: K13 hp, Room Temperature.

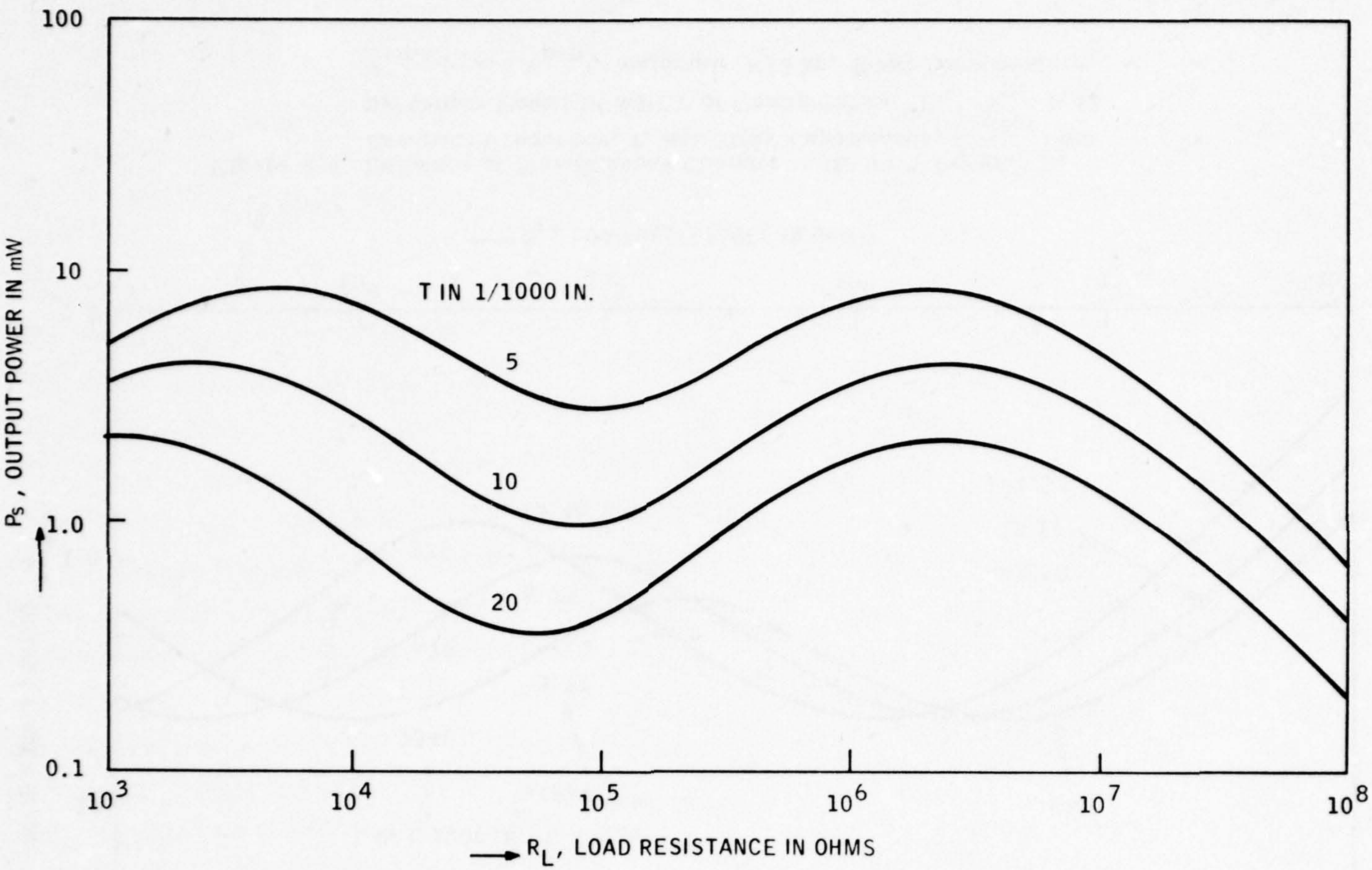


Figure 2-7. Influence of Simultaneous Changes in the PET Thickness, T, and Stray Capacitance, C_{stray}, on the Output Power of a PET of Configuration "B." $V_p = 0.53\ V_{rms}$ ($= 1.5\ V_{p-p}$), Material: K13 hp, Room Temperature.

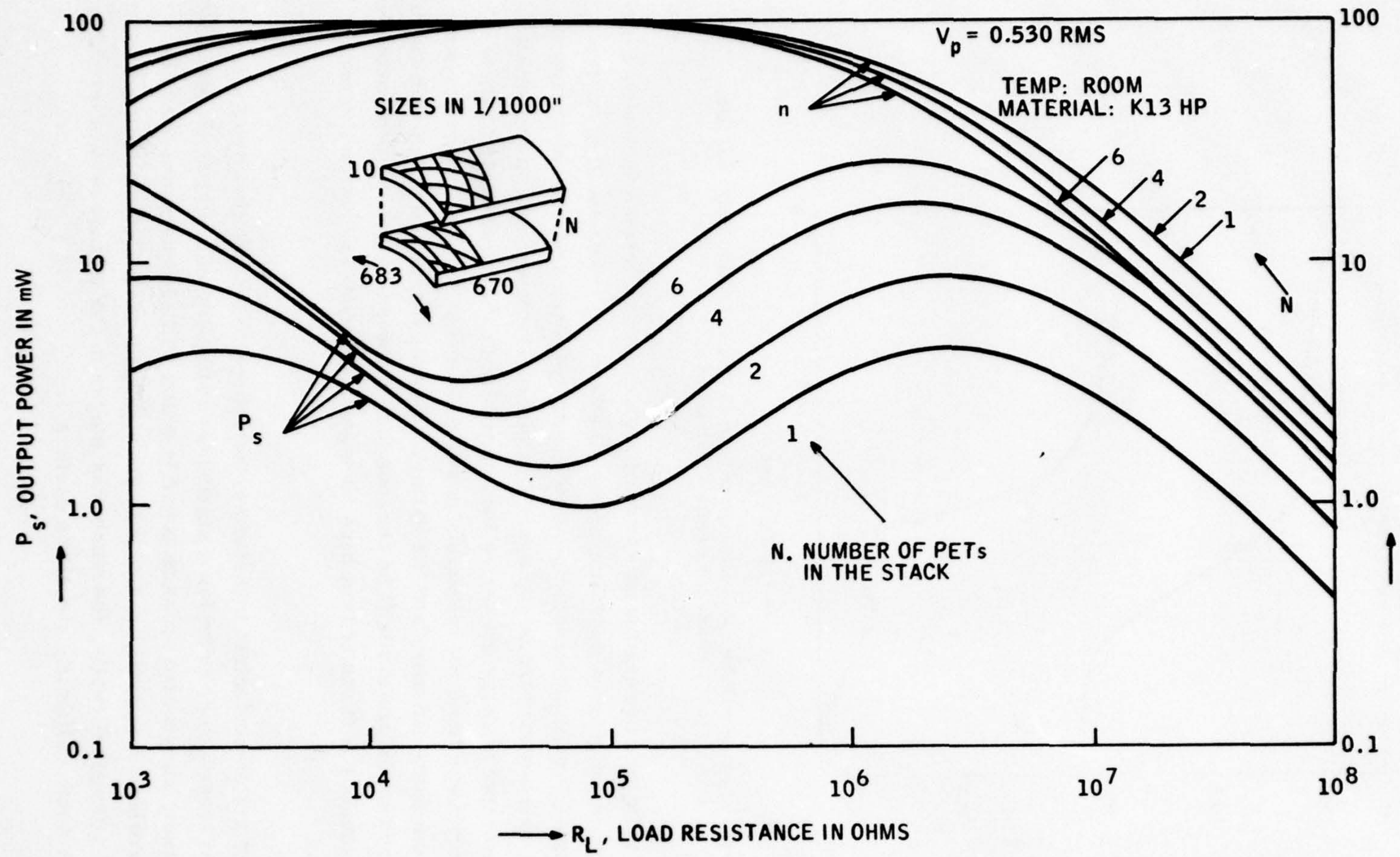


Figure 2-8. The Influence of Stacking Several PETs on the Output Power and Efficiency of a PET of Configuration "B." Constants in V, m, Kg, s - Units:
f = 97.170 kHz, ϵ_{33}^T = 1.300E-8, g_{33} = 2.012E-2, d_{31} = 0.572E-10,
Y_3^E = 7.540E+10, k = 0.630, Q = 1840, ρ = 7600, C_L = 12.0 pF,
C_{stray} = N:6.73 pF, L_p = 0.500, n = 1.

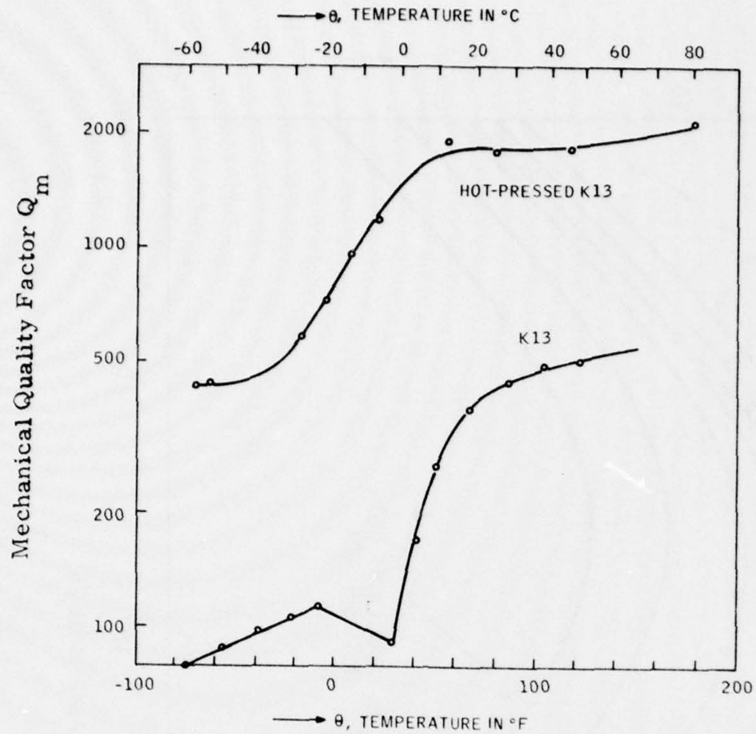


Figure 2-9. Temperature Dependence of the Mechanical Quality Factor for a Hot-Pressed Versus a Sintered K13 Ceramic

The winding capacitances are the major cause of high exciting currents in small, high-gain, wire-wound transformers operating above 10 kHz. The lower exciting currents achieved with the high-gain piezoelectric transformer approach are thus advantageous to the high-gain, wire-wound transformers. The piezoelectric approach is inherently short-circuit protected because excessive loading will shift the piezoelectric power-handling capability away from the maximum power points, and this will prevent excessive loading on the drive circuitry and the battery. In addition, the simple batch-fabricated piezoelectric transformers will be cheaper than the wire-wound transformers that require a great number of turns of fine wire (at significant cost) to provide the necessary voltage gain.

The simplicity of the piezoelectric transformer compared to the complexity of a small, fine, wire-wound transformer provides a significant reliability advantage. A reduction in voltage multiplier stages also appears possible which will also increase the reliability of the piezoelectric approach. Because the high-gain piezoelectric approach can provide the high voltages directly, the number of stages in the voltage multipliers can be reduced, with cost, reliability and space savings.

E. 18MM AND 25MM DESIGN

The design of the 18mm PET package was initially established to allow for a maximum of two washer-shaped piezoelectric ceramic elements with the electrode design shown in Figure 2-10. The exterior of the package was established as shown in Figure 2-11. Six terminals were provided to allow for the greatest amount of freedom for electrodes on the two internal ceramic elements and their interconnections. During the course of the program, it was shown that a single ceramic washer would provide the necessary power output requirements. This was mounted as shown in the cross-section of the package in Figure 2-11. Four primary terminals, P_1^+, P_2^+, P_3^- and P_4^-, were used for the larger split electrodes, while the smaller split electrodes provided the V_{12} and V_3 secondary voltage outputs.

The 25mm PET contained two pairs of half-toroid elements bound togethe and electroded as shown in Figure 2-12. The 25mm PETS initially designed and evaluated in the engineering sample build were packaged as shown in Figure 2-13, which only had five terminals. The lack of a sixth terminal connection limited the use of this design and a sixth electrode pin had to be added. Each pair of the ceramic elements provided a secondary voltage output for the 25mm PET. The 18mm and 25mm elements were spaced in the package as shown in the cross-sections in Figure 2-11 and 2-13. Silicone rubber pads cushion the elements and allow them to vibrate freely.

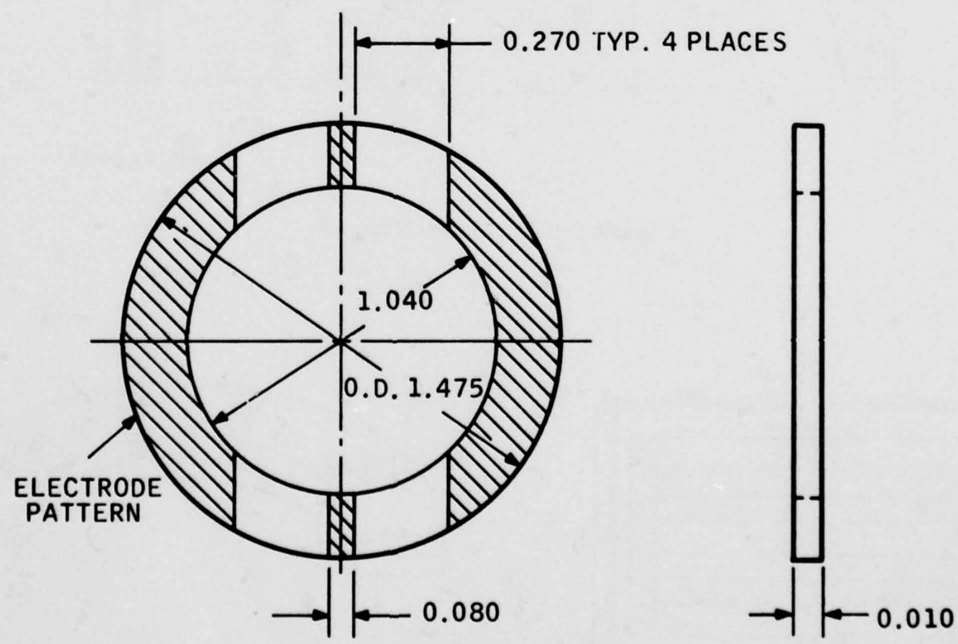


Figure 2-10. 18mm Element

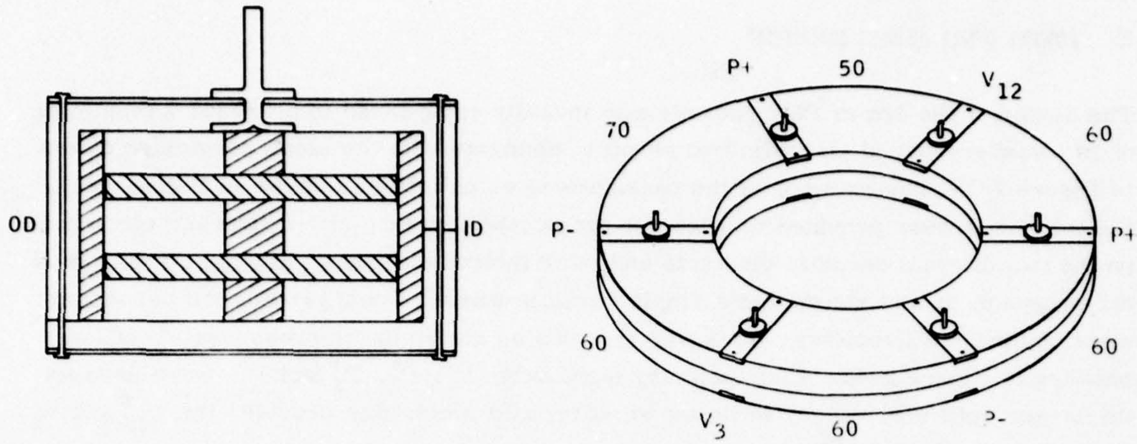


Figure 2-11. 18mm Package Case

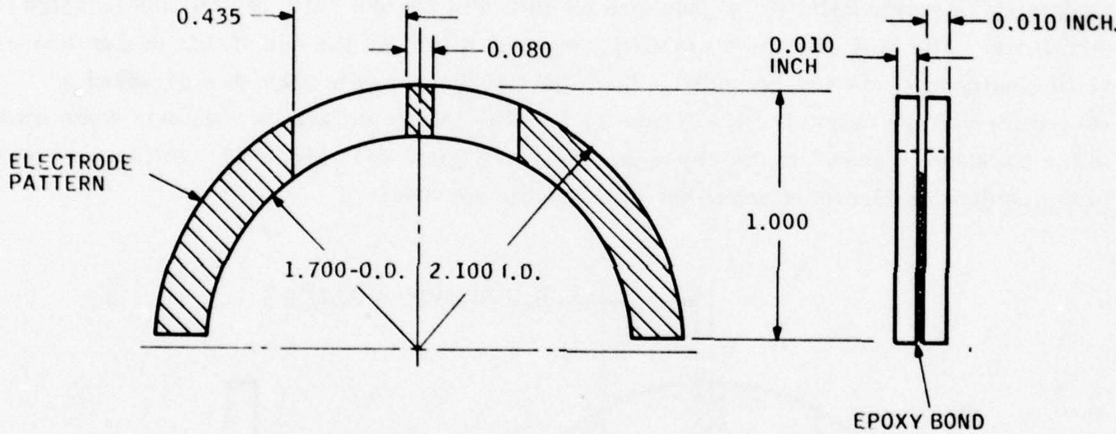


Figure 2-12. 25mm Element

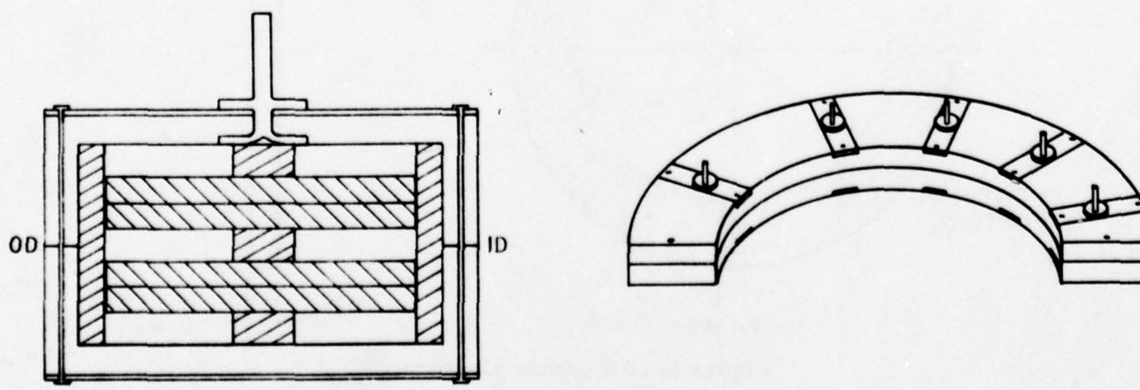


Figure 2-13. 25mm Package Case

SECTION III
PROCESS IMPROVEMENT STUDY

During this program, nine process operations were identified which required improvement to ready the PET approach for manufacturing. These varied from areas which were cost intensive to those which had no existing tooling or process proven for production. Each is discussed below to show what was available at the onset of the program and what was finally developed for the confirmatory samples and pilot run.

A. HOT PRESSING

Objective -- Increase the amount of material produced per hot press slug to increase capacity of existing equipment.

Existing Approach -- The hot pressing approach used prior to the initiation of this effort follows.

A 3-1/4 OD by 2-1/2 ID by 10-inch-long prepress die was filled with 800 grams of material. The material was pressed to 6500 psi and each slug was identified to maintain batch number. A typical slug weighed 800 grams and was 2.5 inches in diameter by 2.1 inches long with a green density of 4.83 gm/cc.

The pressed slug was placed on a pad of MgO grain on a large alumina plate (Figure 3-1). The alumina mold was then set around the slug and the space filled with MgO grain. An alumina spacer was set on top of the slug. Three of these assemblies were loaded into one of 16 hot press kilns. The rams were then put into place and the pressure and temperature applied according to the schedule of Figure 3-2.

After the controlled temperature and pressure profiles were completed, the kiln was allowed to cool to room temperature at its natural rate. The room temperature, hot-pressed assemblies were then removed from the kiln. The grain was removed from the slug and the slug was stored in an envelope identified with the slug number and hot-pressed conditions.

Improvement Study -- In this task, we examined the feasibility of (1) hot pressing larger diameter slugs, (2) hot pressing longer slugs, and (3) continuous hot pressing of 1-inch-thick slugs. A cost analysis of 2.5-, 5.5-, 7.5-inch diameter by 0.8-inch-thick slugs

showed that 1, 3 and 7 slugs, respectively, could be obtained; however, the most effective use of material was gained in going to longer 2.5-inch-diameter slugs. This approach and a continuous hot pressing approach were evaluated with the results shown in Table 3-1. The first three runs used the standard approach with Batch No. 1572 of K-9 PZ-PT to establish the hot pressing temperature of 1270 ± 5°C. Next, three attempts to continuously hot press were unsuccessful because the prepressed slugs cracked prior to reaching peak temperature as shown in Figure 3-3. Some difficulty was also encountered in attempting to hot press an 1800-gram, 5-inch-high slug by the standard single action ram; however, use of a double action hot press die produced good high density material 2.4 inches long as opposed to the normally obtained 0.8-inch-long slugs obtained with 800 grams of material. This approach reduced the hot pressing labor by 60 percent and also had about a 5 percent reduction in labor in four other operations (cold pressing, core drilling, honing and OD grinding) where one part is handled instead of three. The yield of sliced PETs would also be increased from 90 to 96 percent. The density and microstructural uniformity obtained with longer slugs were essentially the same as for the standard slugs originally produced. This approach obviously has significant cost advantage.

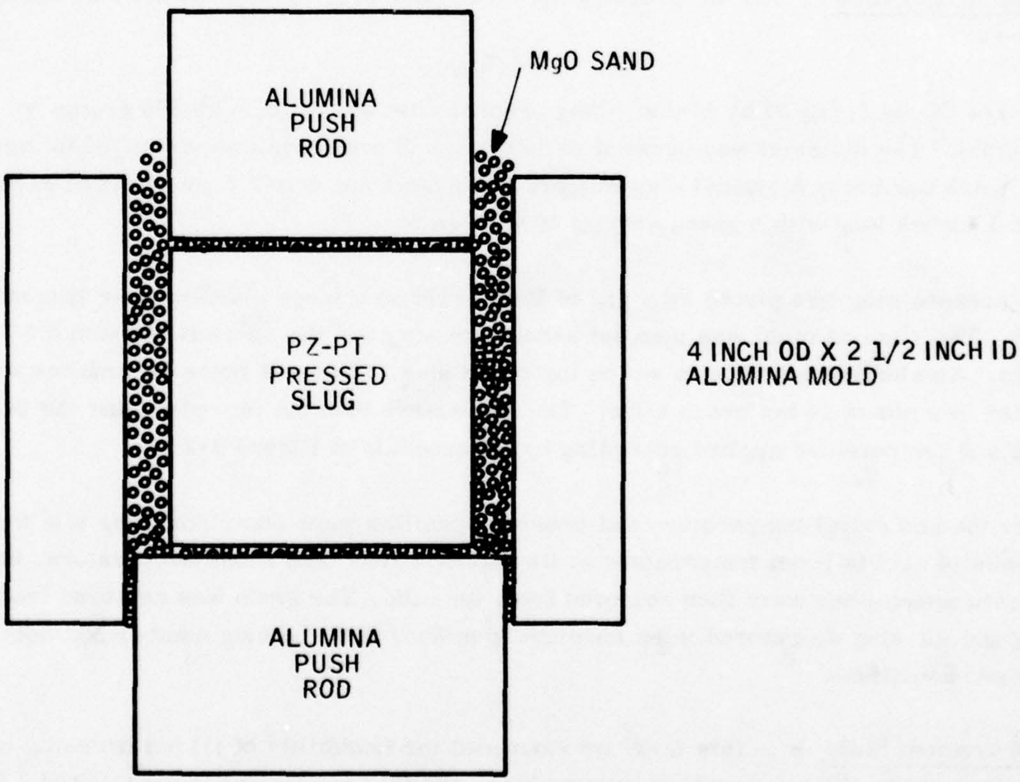


Figure 3-1. Hot Press Die Set-Up

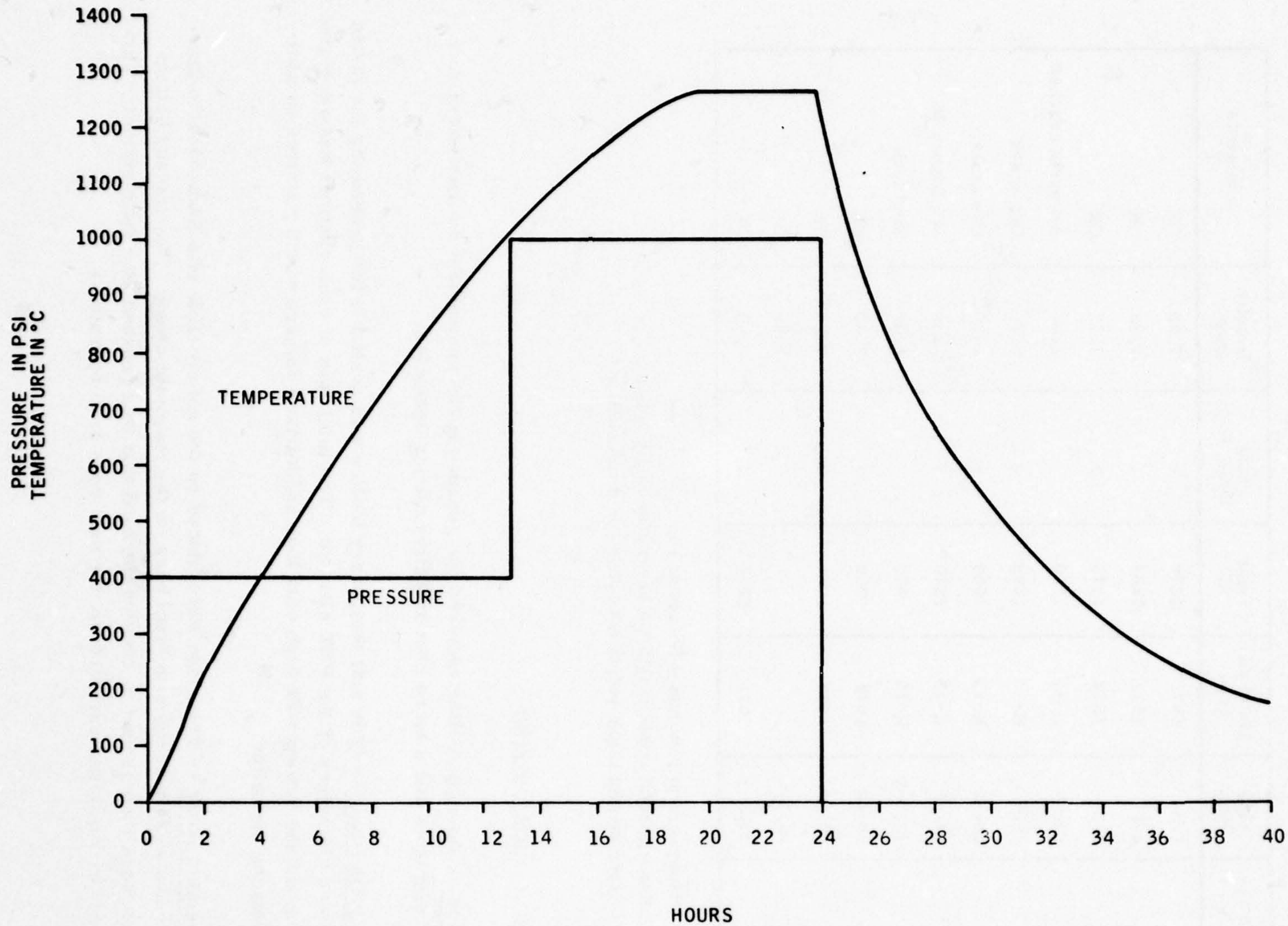


Figure 3-2. Heat and Pressure Schedule for Hot Pressing

Table 3-1. Hot Press Slug Data

Hot Press Run No.	Slug Nos.	Material Type	Temp °C	Soak Time Hrs.	Density gm/cc	Comments
1	1-3	1572	1270	4	7.82	OK
2	4-6	1572	1265	5	7.82	OK
3	7-9	1572	1275	5	7.82	OK
4	CR-1	K-13	1260	-	Low	All parts cracked
5	TRS-1	K-13	1260	4	6.9	One crack
6	CR-2	K-13	1000	-	Low	One crack
7	CR-3	K-13	1270	4	Low	See Figure 26
8	TRD-2	K-13	900	-	Low	Sand leak
9	10-12	1572	1260	5	7.32	OK
10	13-15	1572	1265	3.5	7.80	OK
	16,17				7.80	OK
11	TRD-3	1572	1275	4.5	7.80	OK

CR Experimental continuous hot press run

TRS Experimental triple length hot press run single action

TRD Experimental triple length hot press run double action

B. MECHANICAL SIZING

Objective -- Develop tooling required for generating the mechanical dimensions of K-9 PZ-PT elements and a more cost-effective slicing operation.

Existing Approach -- Only soft temporary tooling was available for generating the inside and outside diameters of the PET element. The thickness of each element was generated by diamond band sawing with high curf loss and surface damage which required an additional lapping operation.

Improvement Study -- The slugs were placed on the rotary table of a Blanchard Surface Grinder and were blocked with steel bars on the magnetic chuck. The top and bottom surfaces were then ground to remove the sand that was pressed into the material. This produced two machined surfaces for the next core drill operations.

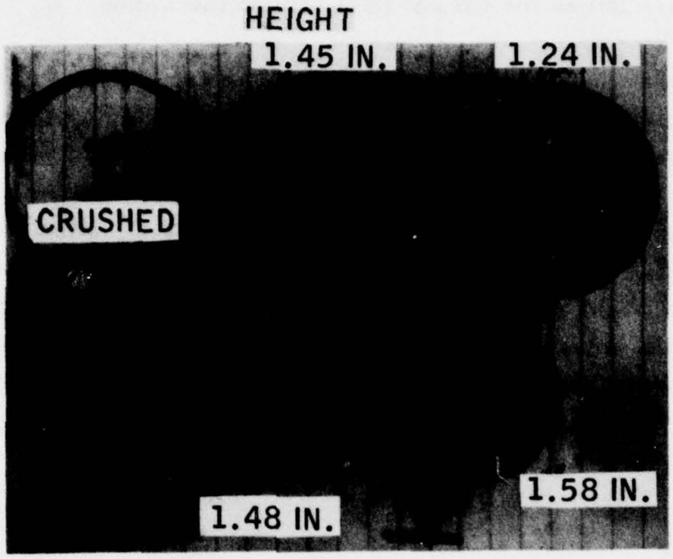
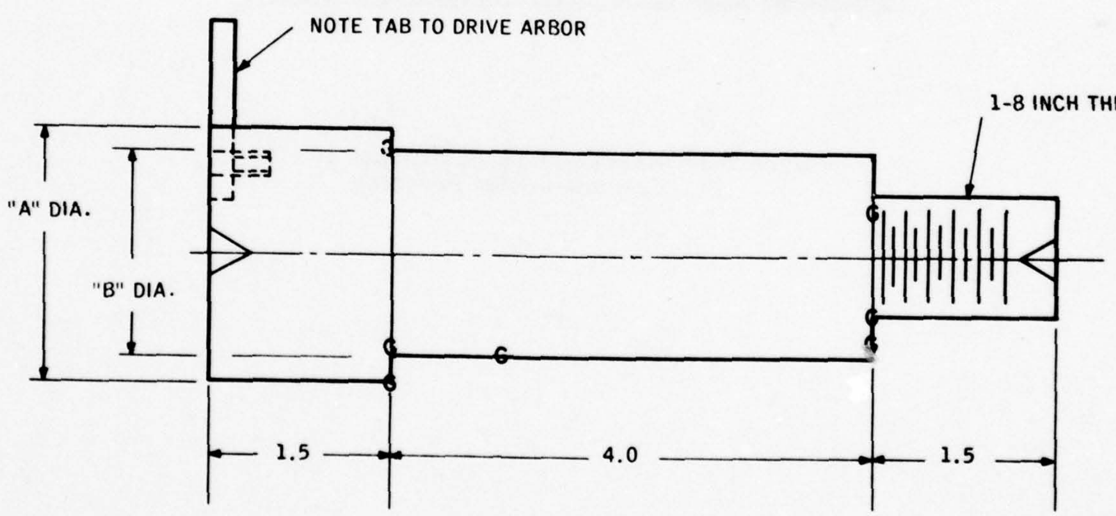


Figure 3-3. Results of Third Attempt at Continuous Hot Pressing

Three core drill operations were used to generate the initial inside and outside diameter of both the 18mm and 25mm PET elements. The first generated the ID of the 18mm element, the second the OD of the 18mm and ID of the 25mm element, and the third the OD of the 25mm element. The core drill was powered by a vertical milling machine. Enough material was left on the OD and ID for finish machining.

A "Sunnen" hone was used to machine the inside diameter. A type of P28 787 diamond hone was used to produce the ID finish to within approximately 0.001 inch of the 1.040 inches and 1.700 inches dimensions required for each type of PET elements.

The slugs were then placed on one of the arbors (Figure 3-4), which were sized for the ID of each type of slug. Next, the arbor was placed between centers and ground to the outside diameter of 1.475 inches and 2.100 inches required for each PET. A Brown and Sharpe No. 1 Universal Grinding Machine was used. The 25mm, 2.1 inch OD by 1.7-inch ID rings were then bound to a mounting plate and a DoAll Diamond bandsaw machine was used to cut each ring into 1.00-inch high, half toroids.



	A	B
PART 1	1.475	1.040
PART 2	2.100	1.700

Figure 3-4. Grinding Arbor

The OD/ID ground slugs (18 or 25mm) were next placed in an oven and sealed to a mounting block with wax. These slugs were diced to the desired 0.010 inch with a Varian 686 Wafering Machine (Varian Lexington Vacuum Division in Lexington, Massachusetts). A schematic of this operation is shown in Figure 3-5.

The Varian Wafering Machine approach described was evaluated using both a coarse 320 mesh boron carbide and fine 600 mesh silicon carbide grit. While the cutting rate of the coarse grit was 0.2 in/hr as opposed to 0.5 in/hr for the finer grit, the coarse grit produces a much rougher surface finish, 125 rms versus 35 rms. The fracture strength of coarse grit cut parts was 50 percent less than the fine grit machined parts. The finer 600 mesh carbide slurry also produced surfaces equivalent in strength to previously produced diamond-sawed and lapped PET elements. The gang-sawing approach appears to reduce the slicing cost by 75 percent, and it eliminates a lapping operation. Thus this approach has been proven for production of the individual 18mm and 25mm PET elements. The Varian equipment was procured by Honeywell and used to produce all elements for the pilot run.

C. ELECTRODING TOOLING

Objective -- Establish the electrode configuration for both 18mm and 25mm PET elements and the silk screening tooling for these operations.

Existing Approach -- Only one electrode design had been evaluated for each of the PET elements and no tooling was available for silk screening.

Improvement Study -- At least seven single and double primary electrode designs were evaluated on the 18mm PET elements and seven designs were evaluated for the 25mm PET elements. Table 3-2 summarizes the data obtained on these units in the free, unpackaged condition. The Type "B" 66 percent double primary/double secondary design has been selected for the 18mm PET elements on the basis that it produced the highest voltage step-up ratio, and it contained no second 45 kHz resonant frequency point. Similarly, Type "J" two bound double primary/single secondary 25mm PETs were selected. Both designs are shown in more detail in Figures 3-6 and 3-7.

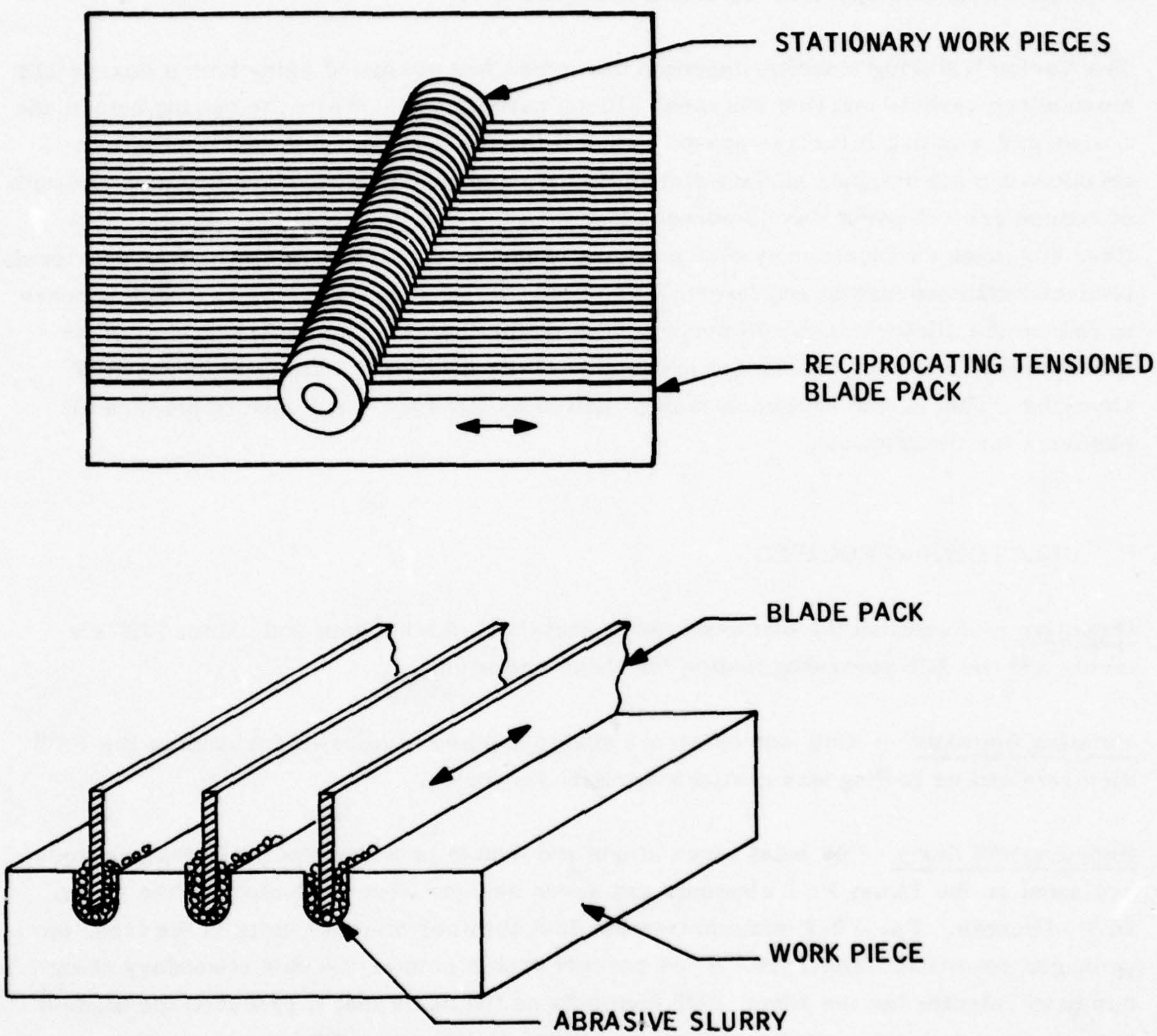


Figure 3-5. Diagram of Wafering Machine for Multiple Slicing of PET Elements

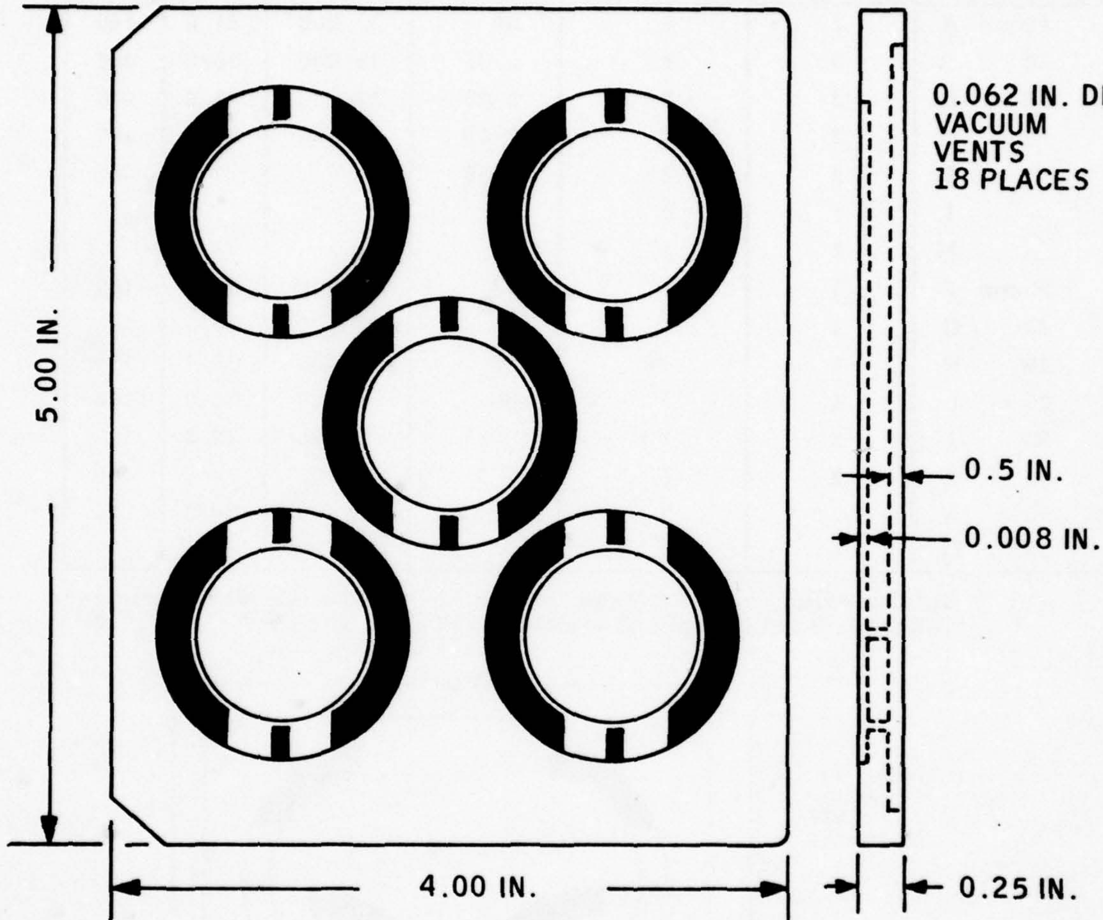


Figure 3-6. 18mm Silk Screen and Nest Tooling Design for Type "B" Electrode

Table 3-2. 18mm and 25mm Unpackaged Test Data for Various Electrode Configurations

Type Trans. and Design		No. Primaries	No. Secondaries	Percent Primary Area	Primary Cap uuf	F_r kHz	V_T^* Volts
18mm	A	1	1	50	12,200	31.6	440
18	B	2	2	2-33	15,000	32.0	460
18	C	2	2	2-25	12,800	31.6	450
18	D	2	2	2-16	7,760	30.9	400
	E	2	2	2-30			
	L	1	2	66			
	M	1	1	58			
25mm	F	1	1	50	15,200	30.5	130
25	G	1	1	60	12,100	30.5	145
25	H	1	1	70	11,500	30.1	135
25	I	1	1	80	8,800	30.3	100
25	J	2	1	2-33	6,600	29.3	150
25	K	2	1	2-25	4,100	28.9	60
25	N	1	2	66	15,400	30.2	74
25	Q						

*Vt = Total parallel output for single and double secondaries where primary voltage is 2 volts (p-p) and loads are 10^7 ohms and 10 pf.

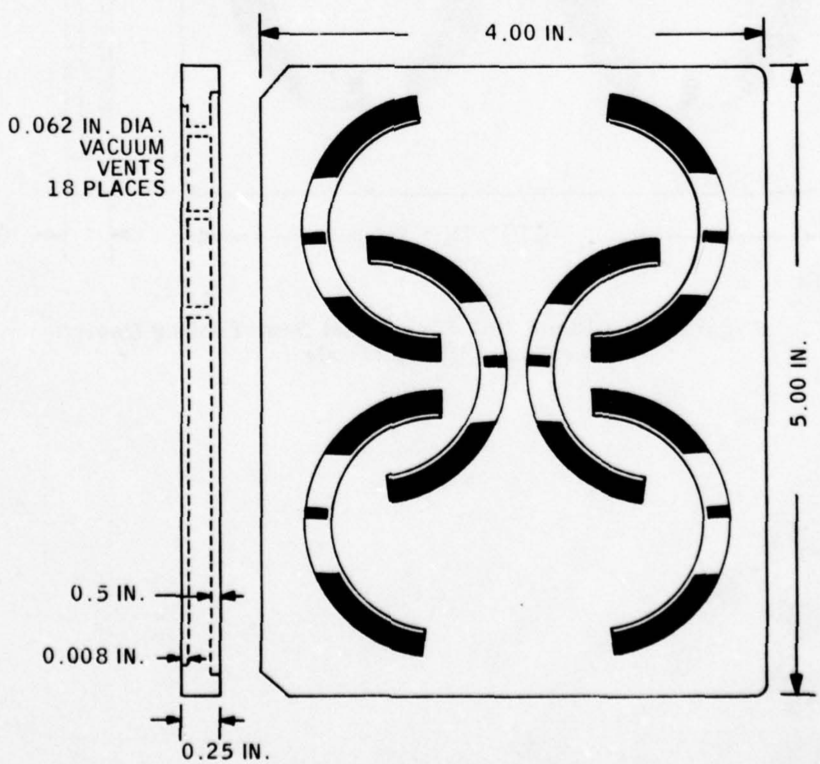


Figure 3-7. 25mm Silk Screen and Nest Tooling Design for Type "J" Electrode

Several other designs are shown in Figure 3-8. The Type "E" design is a modification of the Type "B" first engineering sample electrode design where a nonsymmetrical output voltage was achieved from each secondary electrode and where a separate feedback electrode was added to one positive primary electrode. Dual units such as these were built and packaged with the results shown in Table 3-3. As expected, the two parallel outputs of the V_{12} produced only 600 volts (step-up ratio of 120) versus 1010 volts (step-up ratio of 202) for the parallel outputs of the V_3. This approach would allow better matching of the output voltages to two different load requirements, such as required in this program, but was not pursued further because this approach required two elements.

Table 3-3. Output Characteristics of 18 and 25mm PETs for 5 Volts Peak-to-Peak Input

Type Electrode Design	Resonant Frequency (kHz)	Input Current (ma)	Output Voltage	
			V_{12}	V_3
Packaged 18mm, Type E	31.86	82.8	603	1010
Packaged 18mm, Type M	30.79	73.2	460	505
Packaged 25mm, Type Q	29.55	177.8	455	745

The type M electrode design allowed one element to provide V_{12} and a second element V_3. The staggered secondary electrode allowed the dual-element assembly to have two isolated secondary electrodes. The single primary electroded area allowed fewer interconnecting electrodes; for instance, only four terminals were required with this design. Table 3-3 shows the results obtained with a packaged unit of this design. The V_{12} and V_3 outputs were 460 and 505 volts with a step-up ratio of less than 100, high primary input current and thus low efficiency.

The type L electrode configuration was also evaluated for the 18mm PETs, but the units were poorly poled, arcing was common and the input current was still higher than the type M design. Upon consultation with the technical monitor, it was concluded that an electrode design change would be too risky. Therefore, the split primary, dual secondary electroded type "B" design used for the first engineering samples was selected for the second engineering sample build.

The single primary, dual primary type Q 25mm electrode design shown in Figure 3-8 was also built and evaluated. Four such units were bound together and interconnected in

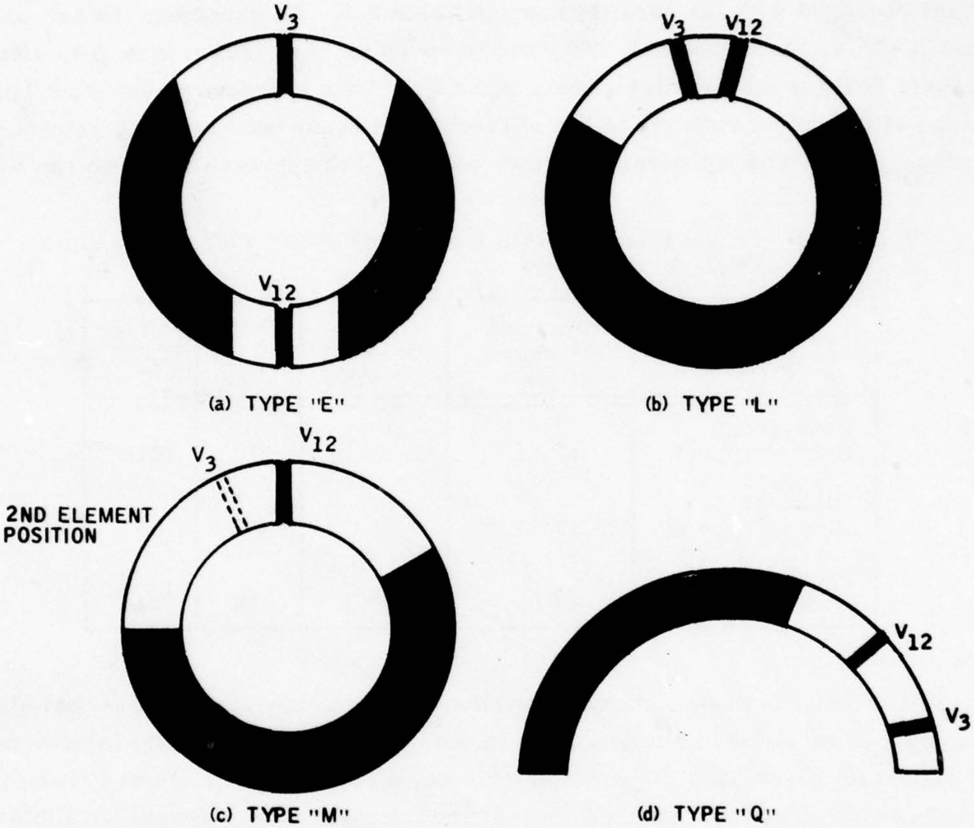


Figure 3-8. 18mm and 25mm Element Electrode Designs

parallel to provide a four-terminal package unit with the properties given in Table 3-3. The results obtained were also lower than the first engineering samples built; therefore, the original 25mm electrode design was also selected for the second engineering sample build.

A semiautomatic silk screening operation for applying silver paste to the PET was established for an existing automatic applicator. The patterned silk screens and nest are shown in Figures 3-6 and 3-7. The secondary electrode is applied over the edge during this operation. The silver is then dried on the parts and the opposite side printed and dried.

D. POLARIZATION TOOLING

Objective -- Establish semiautomatic polarization tooling and a power supply for poling the 18mm and 25mm PET elements.

Existing Approach -- Only soft tooling was available for poling one element at a time. The primary and secondary sections of the PET had to be polarized as separate operations.

Improvement Study -- A rotary poling station, which held eight 18mm or 25mm elements, was designed and built as shown in Figure 3-9. The rotary wheel held eight separate poling fixtures, as shown in Figure 3-10, which each held an individual element. The elements were first loaded in the poling fixture and the fixture was then plugged into the rotary wheel at the 45° position, rotated clockwise to 90° for gradual heating above the oil, at 135° preheating in oil occurred, at 180° for primary section poling at 1500 volts, at 225° for secondary poling at 27 kV for the 18mm or 16.5 kV for the 25mm elements, at 270°, 315 and 360° for cooling and unloading. The parts are then removed from the fixture, vapor degreased and stored for next stage assembly.

This procedure was quite reliable; however, care was required to make certain the part was loaded in the fixture correctly without breaking the element. The production rate was low (about 60/hr), but a larger poling station with additional fixtures could be scaled in size to double the output of this unit.

The polarization supply shown in Figure 3-11 uniquely provided both voltage levels to the poling station.

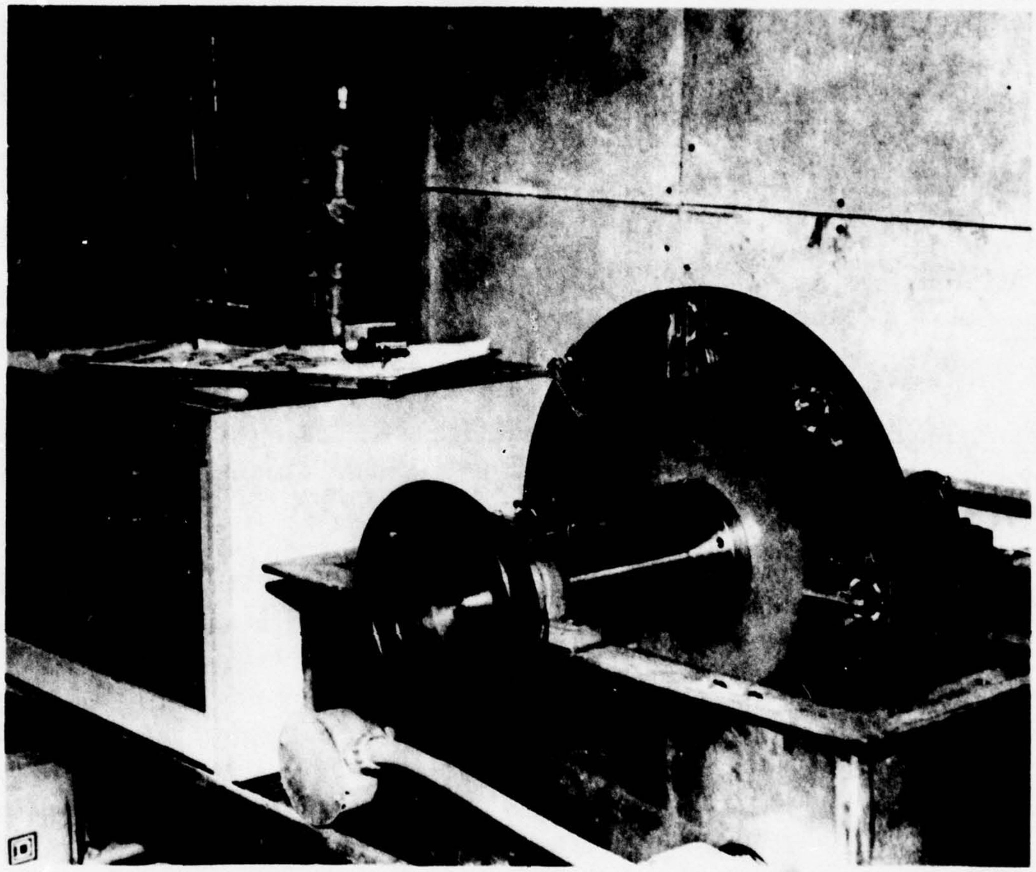


Figure 3-9. Rotary Poling Station

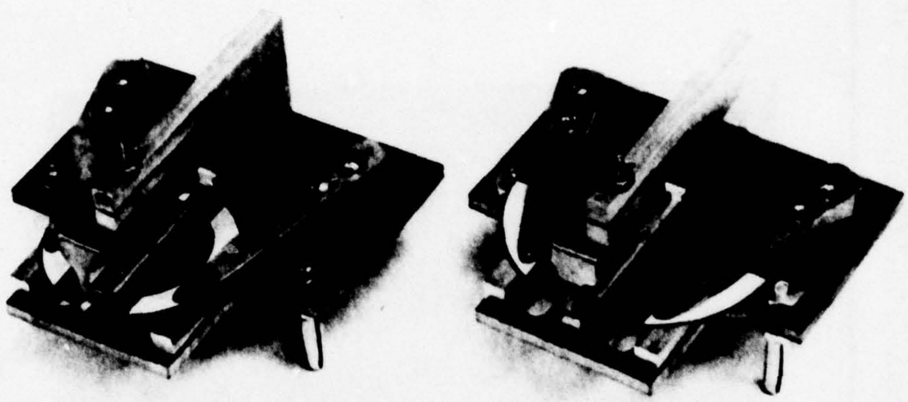


Figure 3-10. 18mm and 25mm Poling Fixture

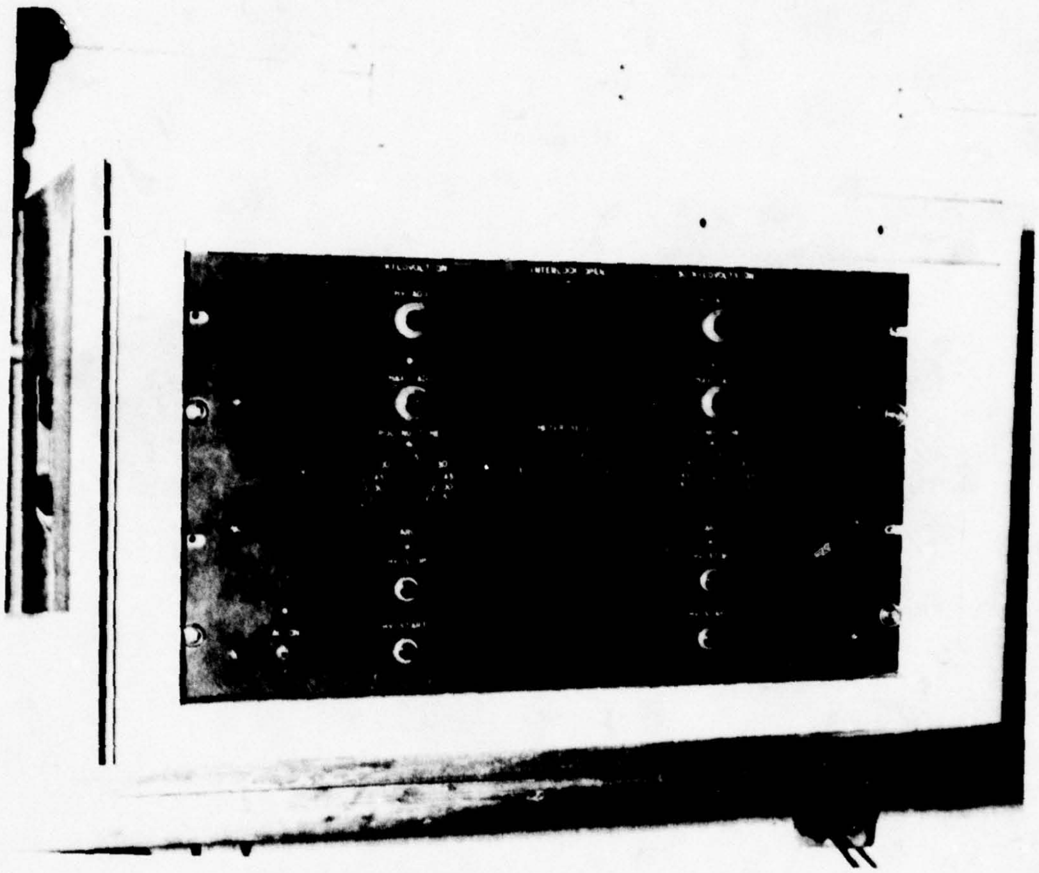


Figure 3-11. Polarization Power Supply

E. PET PACKAGE

Objective -- Design a thin wall package to hold the 18mm and 25mm PET elements and the tooling for producing such packages.

Existing Approach -- Only prototype packages machined from fiberglass reinforced epoxy plastics had been made for the 18mm PETs prior to the start of this program.

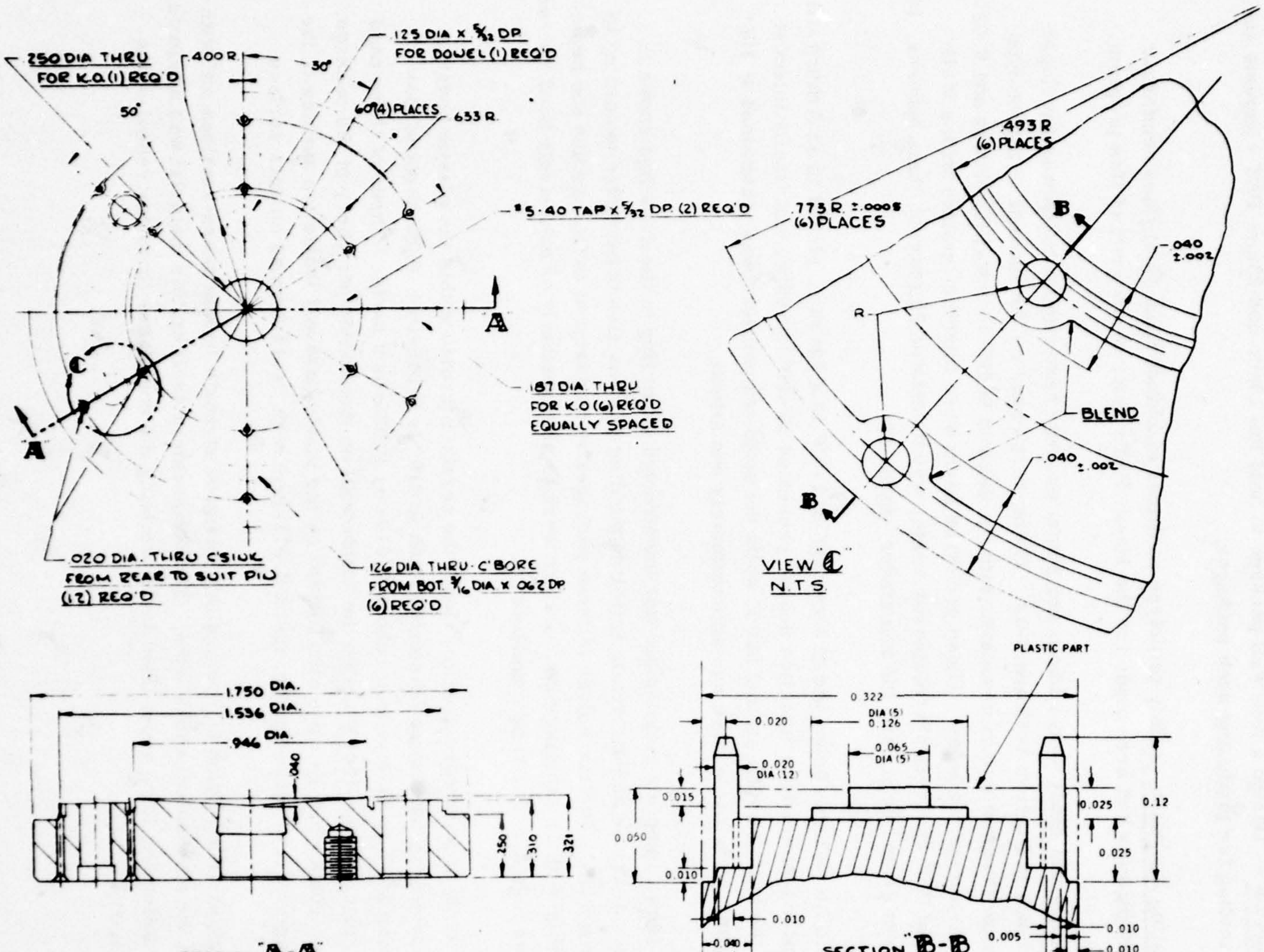
Improvement Study -- An 18mm and 25mm package case configuration was developed as shown in Figures 3-12 and 3-13. These were based on the success of a prototype package that was injection-molded with the desired 0.025-inch wall thickness and 0.020-inch-diameter pin holes. These prototype parts were injection-molded with a Well-a-meld GSF 25-15-66 thermoplastic resin, which contains 25 percent glass spheres, 15 percent glass fibers, and the remainder, Nylon 66.

This material was dried two to six hours at 175°F in a vacuum, placed in an Arburg All Rounder 30mm screw injection press, preheated to 490° to 590°F, and finally injected into the mold at 4000 psi and 500°F while the mold temperature was maintained at 100° to 130°F. The cycle time was approximately one minute.

The 18mm injection molding die was constructed according to the drawings shown in Figure 3-12. A similar 25mm injection molding die was also constructed according to Figure 3-13. The two halves of these packages were designed to fit together and be held together with 12 shorting pins. Future work to ultrasonically or adhesively bond the two halves together should be considered.

Elastomeric pads were used to "float" the ceramic toroids within the plastic housing. The periphery pads were fabricated from 0.010- to 0.015-inch-thick sheet of Dow Corning 2097 or 3110 silicon rubber 0.010- by 0.020-inch parts. Three of these pads were placed about 120° apart on the inside wall on the outside periphery of the package. Silicon rubber bumps were also formed on the inside base and inside top surface of the package. Six of these bumps, about 0.015-inch high, were formed on each surface.

The glass-filled Nylon 66 composition had good strength in thin cross-sections and withstood the mechanical shock tests. The temperature limit on this material was adequate, but caution had to be excercised in determining the resistance to solder reheat of the packaged PET.



PET Top Half

Figure 3-12. Package Molding Dies - 18mm

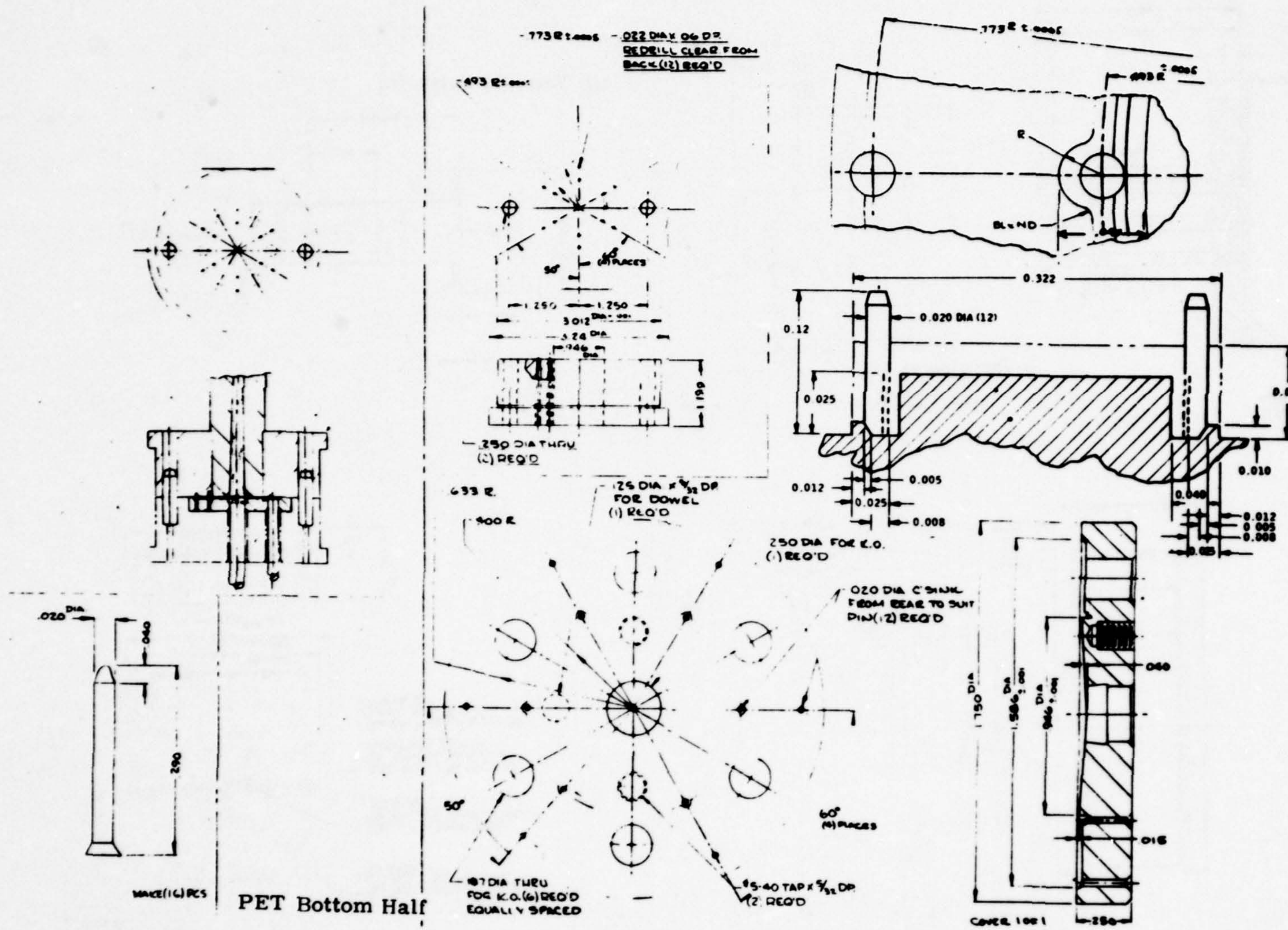
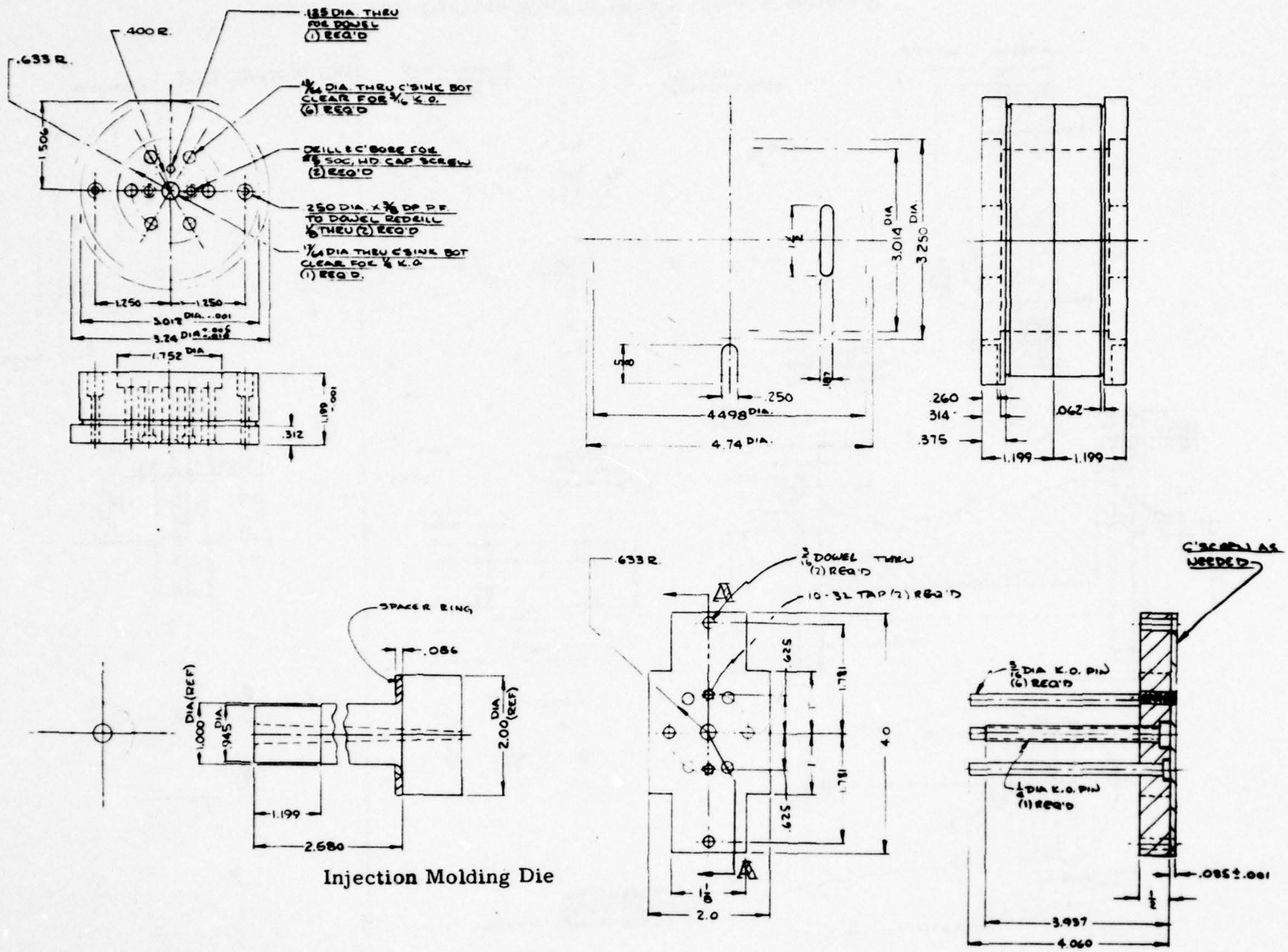


Figure 3-12. Package Molding Dies - 18mm (Continued)



Injection Molding Die

Figure 3-12. Package Molding Dies - 18mm (Concluded)

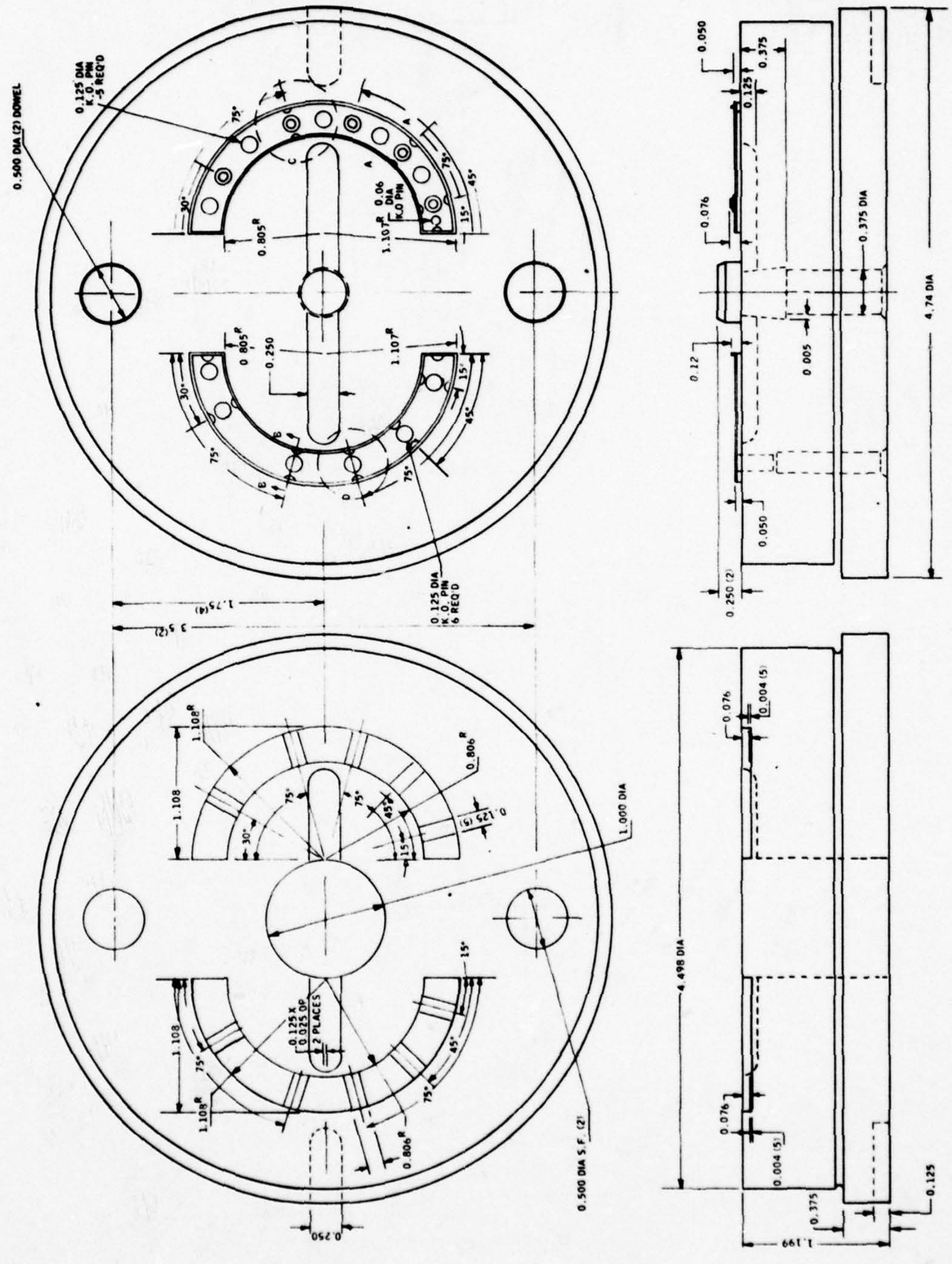


Figure 3-13. Injection Molding Die - 25mm

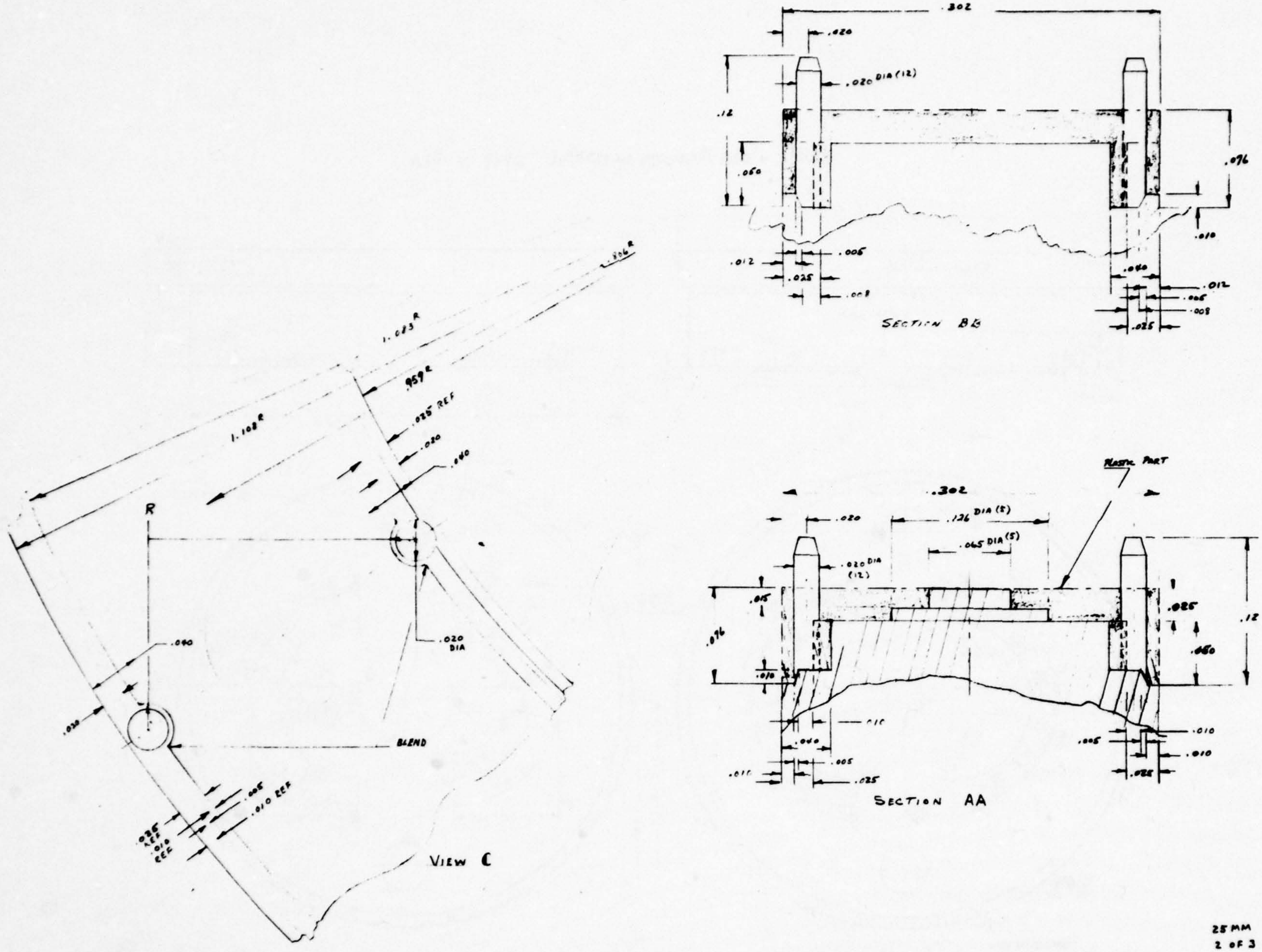


Figure 3-13. Injection Molding Die - 25mm (Continued)

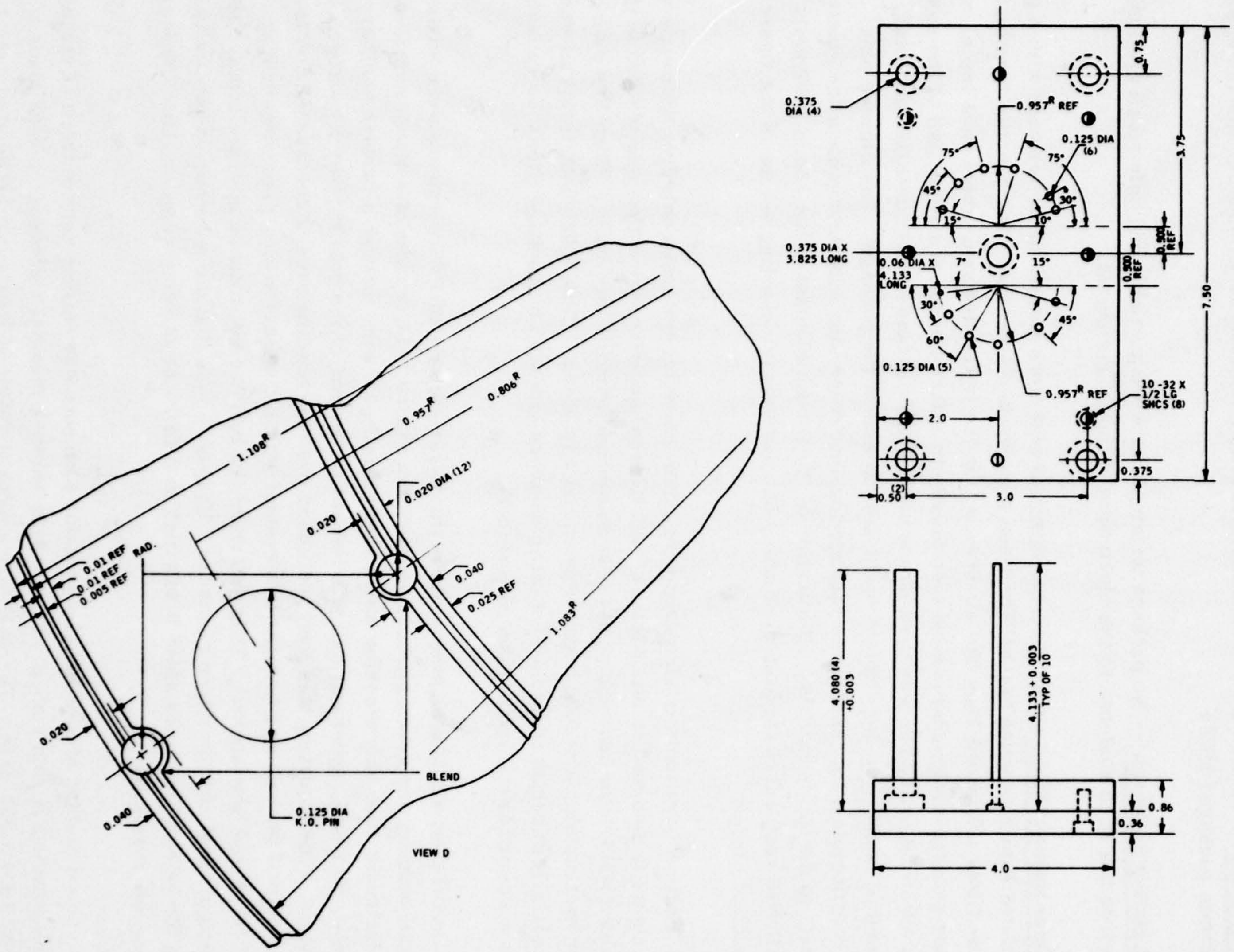


Figure 3-13. Injection Molding Die - 25mm (Concluded)

F. INTERCONNECTIONS

Objective -- Establish reliable electrical interconnection techniques for the 18mm and 25mm packaged PETs.

Existing Approach -- No package terminations were available and only small pretinned wires had been soldered to the electrodes of the PET element.

Improvement Study -- Six external terminal pins were staked on the top case with a gold plated Kovar shorting bar held between the terminal and case. The specific terminal used was a Concord Part No. 10-867-1A. In the initial designs, which used two elements per package with each mounted individually in either the top or bottom half of the case, a second shorting bar was used on the back of the package for a convenient external method connecting the element in the bottom half of the package. The closure pins (shorting pins) for holding the package together were then used to complete the electrical path to the top terminals. Elimination of the second element in the 18mm PET units allowed removal of the bottom shorting bar and took the shorting pin out of the interconnection circuit.

A similar iteration was also used with 25mm package; however, only five terminals were originally designed in this package. An internal negative connection was planned originally which would eliminate the need for two negative primary terminals. When this did not prove feasible, a second negative terminal was added. This 0.020-inch terminal was radically different from the five other stake-on types. The package should be redesigned to accommodate a sixth stake-on terminal.

Several methods of attaching leads to the silver electroded PET elements were studied. Ball bonding was accomplished, as shown in Figure 3-14, by use of a standard microelectronic assembly machine which feeds small gold wire through a carbide capillary tube. A small, spherical ball was formed on the end of the gold wire by a hydrogen flame. The capillary was then positioned over the bonding area of the washer and lowered until the ball was brought into contact with the washer with a predetermined amount of force and heat applied. This deformed the ball and established intimate contact between the gold ball and the silver electrode. However, note that the wire comes vertically out of the ball and occupies about 0.015 inch to 0.020 inch of vertical space. Such space was not available.

A second method of attaching leads to the elements was employment of thermal compression bonding of gold ribbon. Figure 3-15 shows a thermal compression bond made with 3 by 10 mil gold tape. The gold tape approach required less space between elements and contained multiple bonds to improve the reliability of the interconnections. This

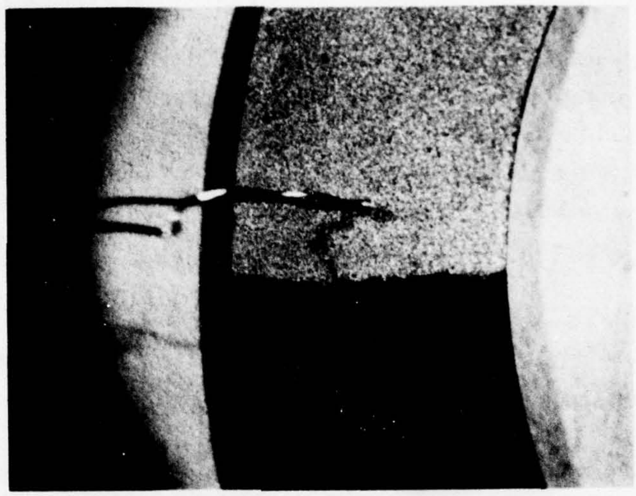


Figure 3-14. Gold Bead Bond on 18mm Element

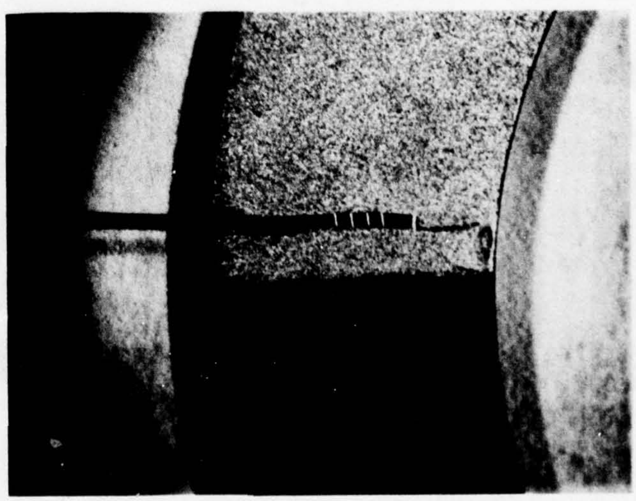


Figure 3-15. Thermal Compressional Gold Bond on 18mm Element

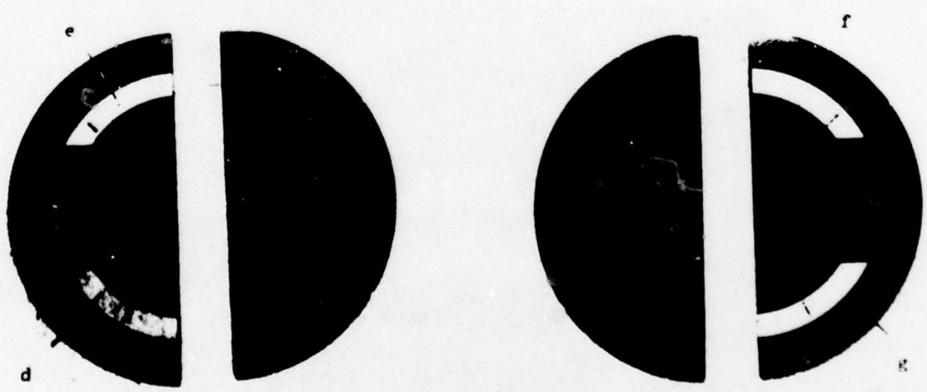
approach appeared to be a good interconnection method and was used to produce the 18mm and 25mm first engineering samples. Many elements were broken during this approach; therefore, it was discontinued in the second engineering sample build.

The gold ribbon was soldered directly to the silver electrode by pretinning a very small area with about a 0.005-inch-thick layer of solder and then soldering the gold ribbon to this area with virtually no additional solder.

Lead location fixtures such as those shown in Figure 3-16 were used to hold the gold ribbon at the proper angle. The gold wires were then bent to 90° with a small stress-relief loop and inserted through the package holes and soldered to the top shorting bar. Those leads adjacent to the top case were fed through the center hole of the shorting bar. Those leads on the botton were fed behind a rubber pad through a hole adjacent to the closure pin hole and soldered to the shorting bar.

Where stacks of 25mm elements were bound together with epoxy resin, a conductive silver-epoxy resin contact was used between the gold lead and silver electroded element. These were also electrically isolated from the other electroded surfaces with a small piece of silastic rubber.

Additional work of the interconnection method is still warranted to decrease the amount of soldering required. Soldering the leads directly to the case terminal would eliminate the need for the top shorting bar.



(a) Welded Leads Side One for Bonded AB PETs

(b) Welded Leads Side Two for Bonded AB PETs

Figure 3-16. 25mm Welding Fixture and Approach

G. TEST EQUIPMENT

Objective -- Establish the equipment and test fixtures required for in-process control and final inspection of the packaged 18mm and 25mm PETs.

Existing Approach -- Only soft fixtures, manual frequency scanning equipment and an oscilliscope voltage output readout were available for evaluating the PETs prior to this program.

Improvement Study -- A PET test console (Figure 3-17) was designed and built to provide the required parameter information on each packaged 18mm or 25mm PET. The drive frequency was automatically swept through a limited range to detect and lock-on the resonant frequency. Readout of output voltage, resonant frequency, input voltage and input current was also provided. Details of the circuit, fabricated from a number of standard integrated circuits and components, are presented in Figure 3-18. This console provided functional versatility, repeatability of parameter measurements and rapid measurements to reduce test and measurement time and cost.

Basically, the circuit consists of a voltage-controlled oscillator which sweeps the drive amplifier through the frequency range in search for the PET resonator frequency. When a resonant point is found, the circuit dwells at the resonant frequency and the parameter measurements of input current, input voltage, V1 and V2 output voltages, and the operating frequency are made by digital test instruments which have BCD outputs for eventual printer capability. From these measurements the transformer step-up ratio, power and efficiency were easily calculated.

The test console also provided a versatile means of testing and measuring the PETs for both in-process assembly testing as well as testing of the assembly line end product. This unit was not satisfactory for monitoring PET operation during environmental tests; therefore, separate life test drive circuits were designed and built for that purpose. The power supply and life test holding fixtures are shown in Figure 3-19. Figure 3-20 shows the circuit and chassis wiring diagrams used for the two modules built for this purpose. Each console drove as many as six PETs at 125 percent of their rated input voltage and at the resonant frequency of each transformer. The tester continuously monitored the PET for shorts and abrupt changes in input current.

The test console was also used to monitor the performance of the PETs during vibration, humidity or other types of environmental testing. All of this equipment worked quite well. Care was taken to make certain that good electrical contact was made to all terminals on the PET.

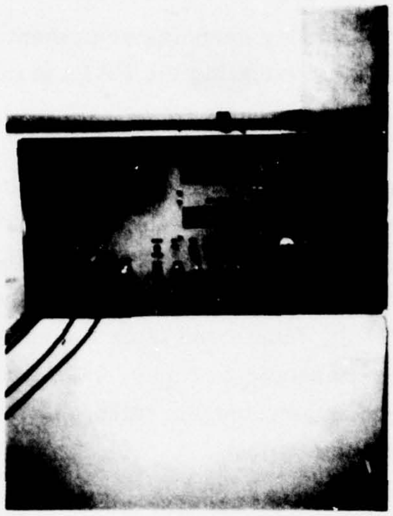
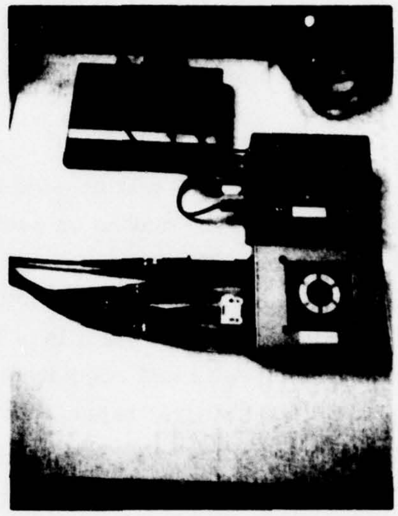
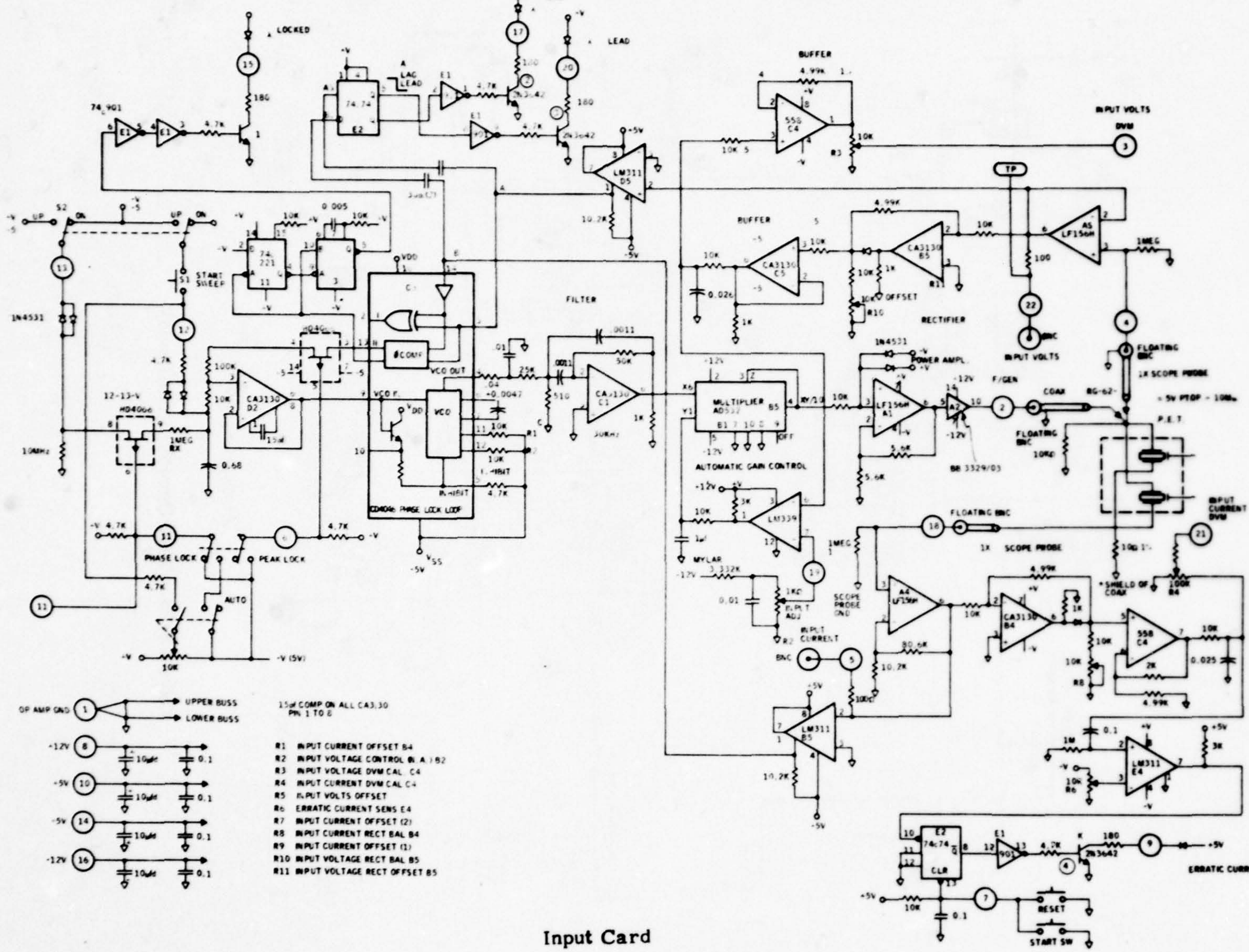
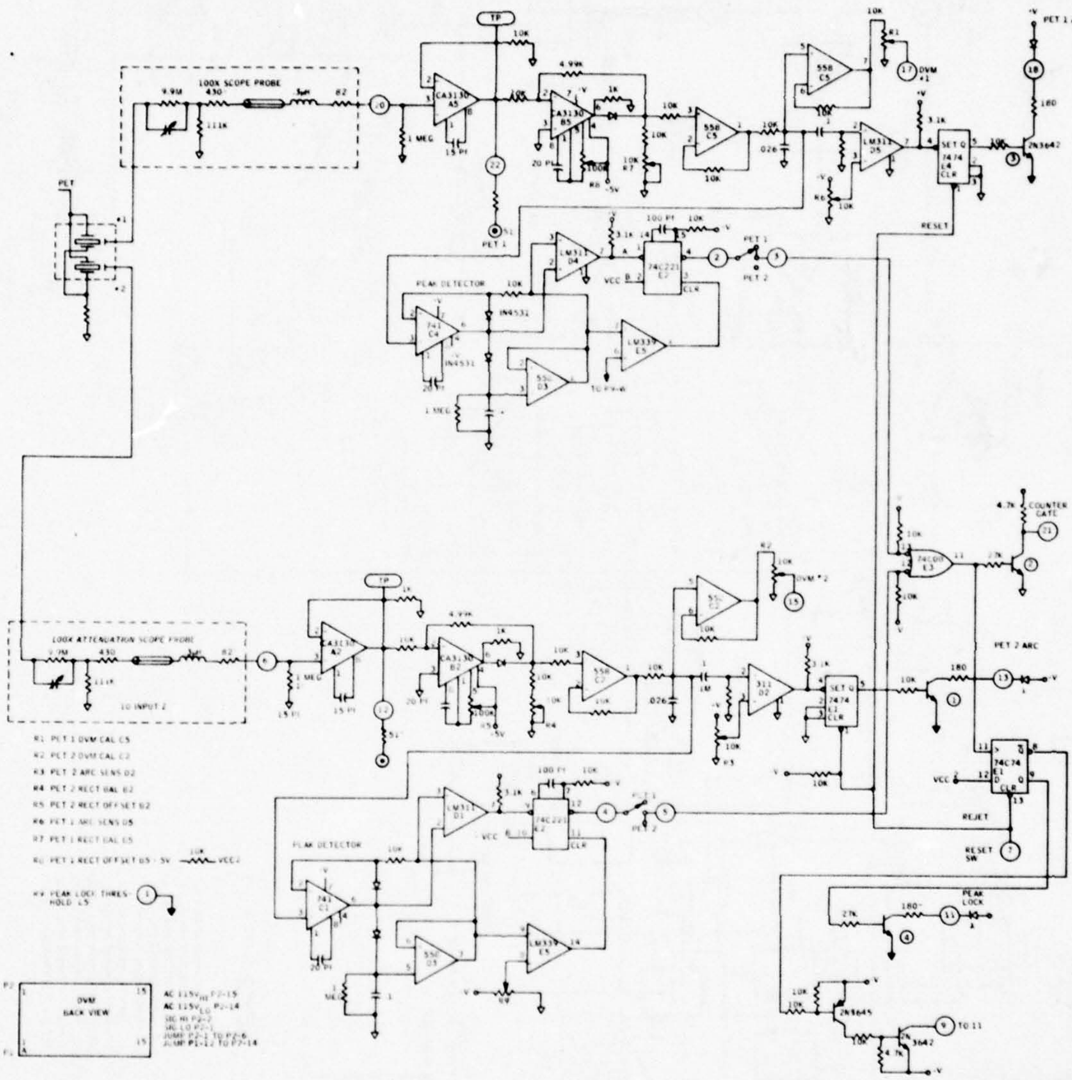
 

Figure 3-17. Automatic Test Console and Test Fixtures



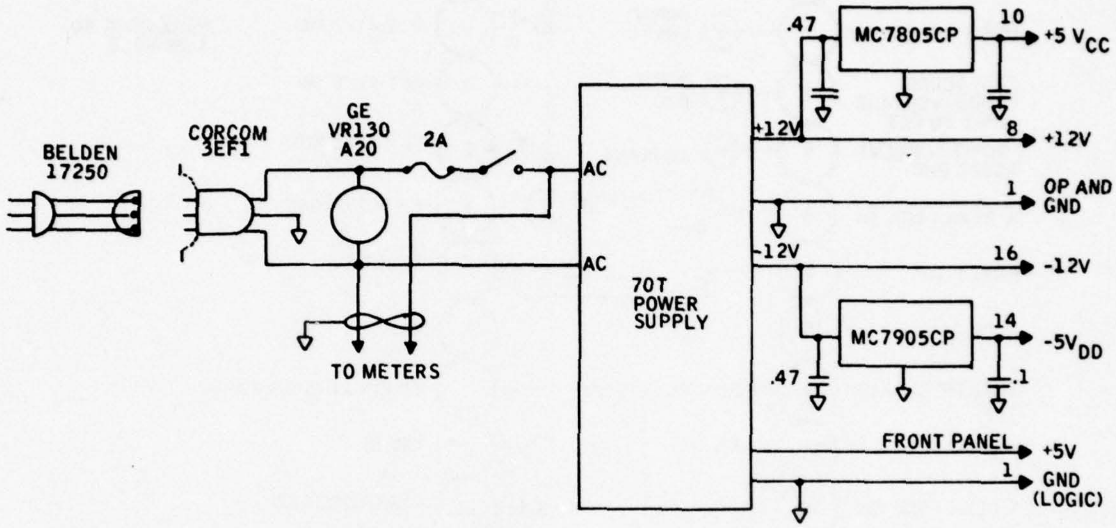
Input Card

Figure 3-18. Test Console



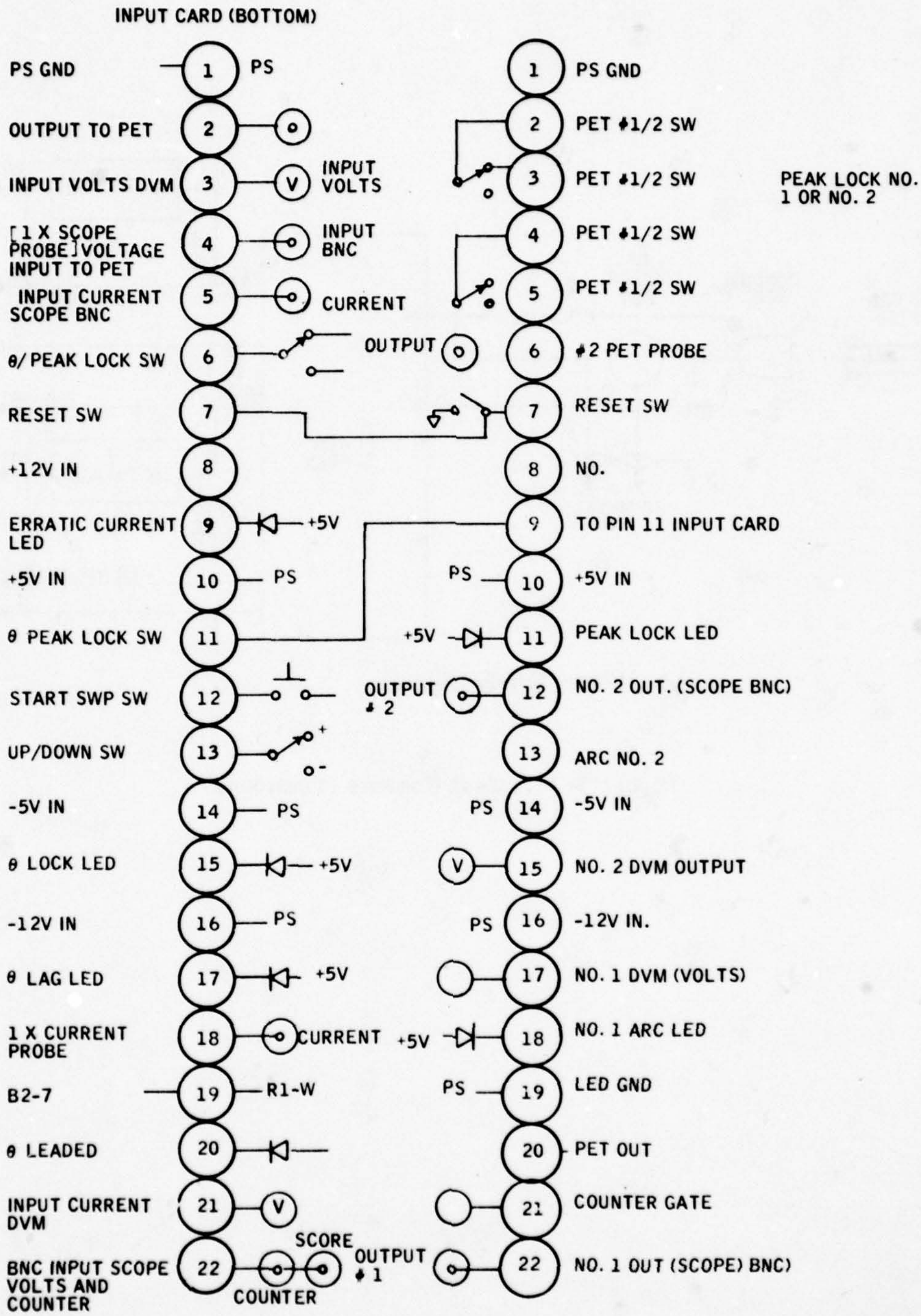
Output Card

Figure 3-18. Test Console (Continued)



Power Supply Diagram

Figure 3-18. Test Console (Continued)



Schematic For Main Frame Interconnect Wiring

Figure 3-18. Test Console (Concluded)

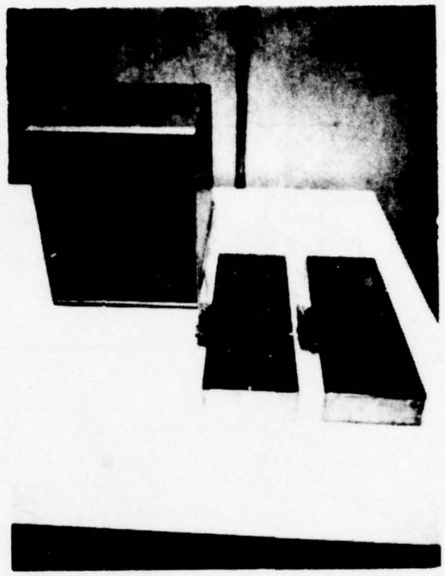
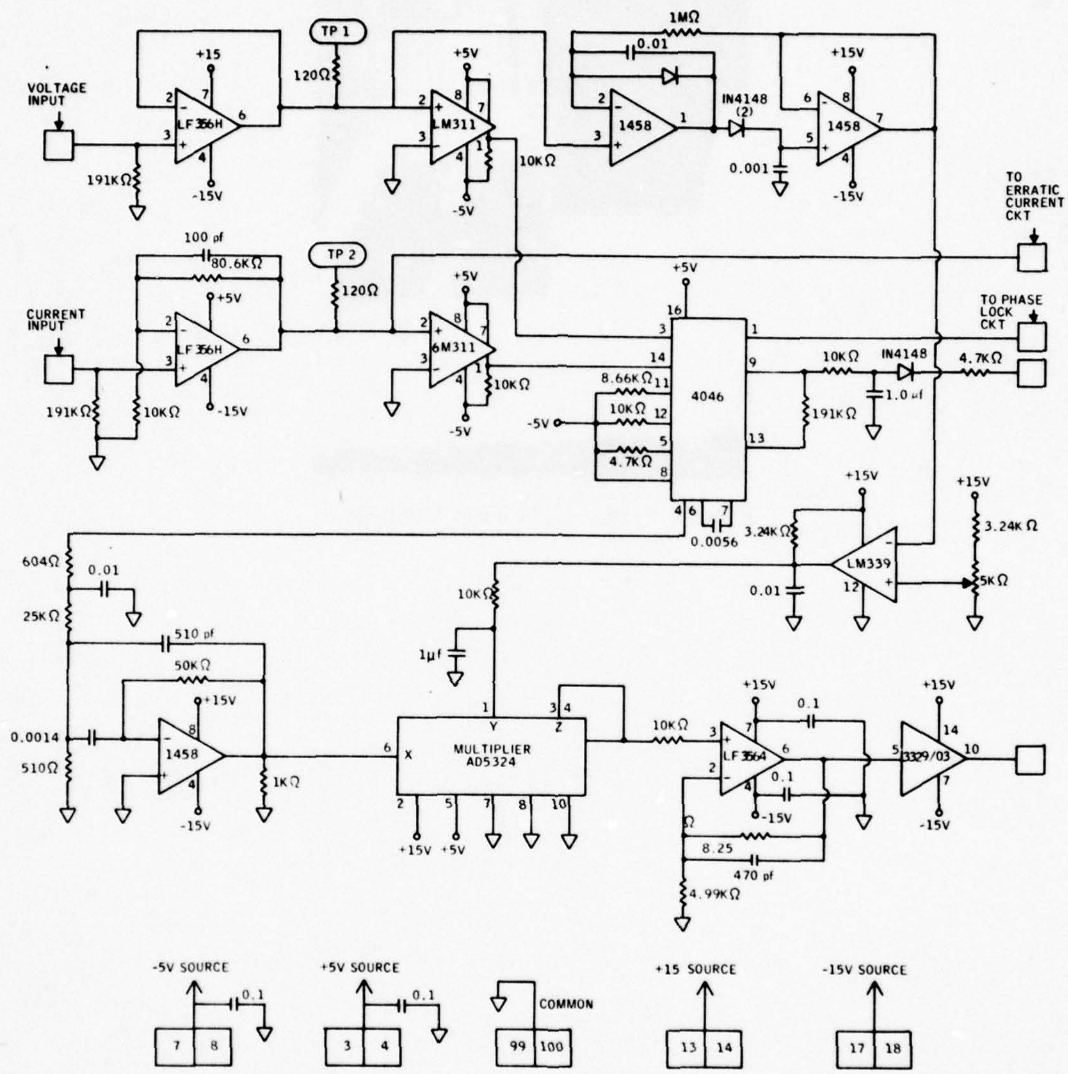
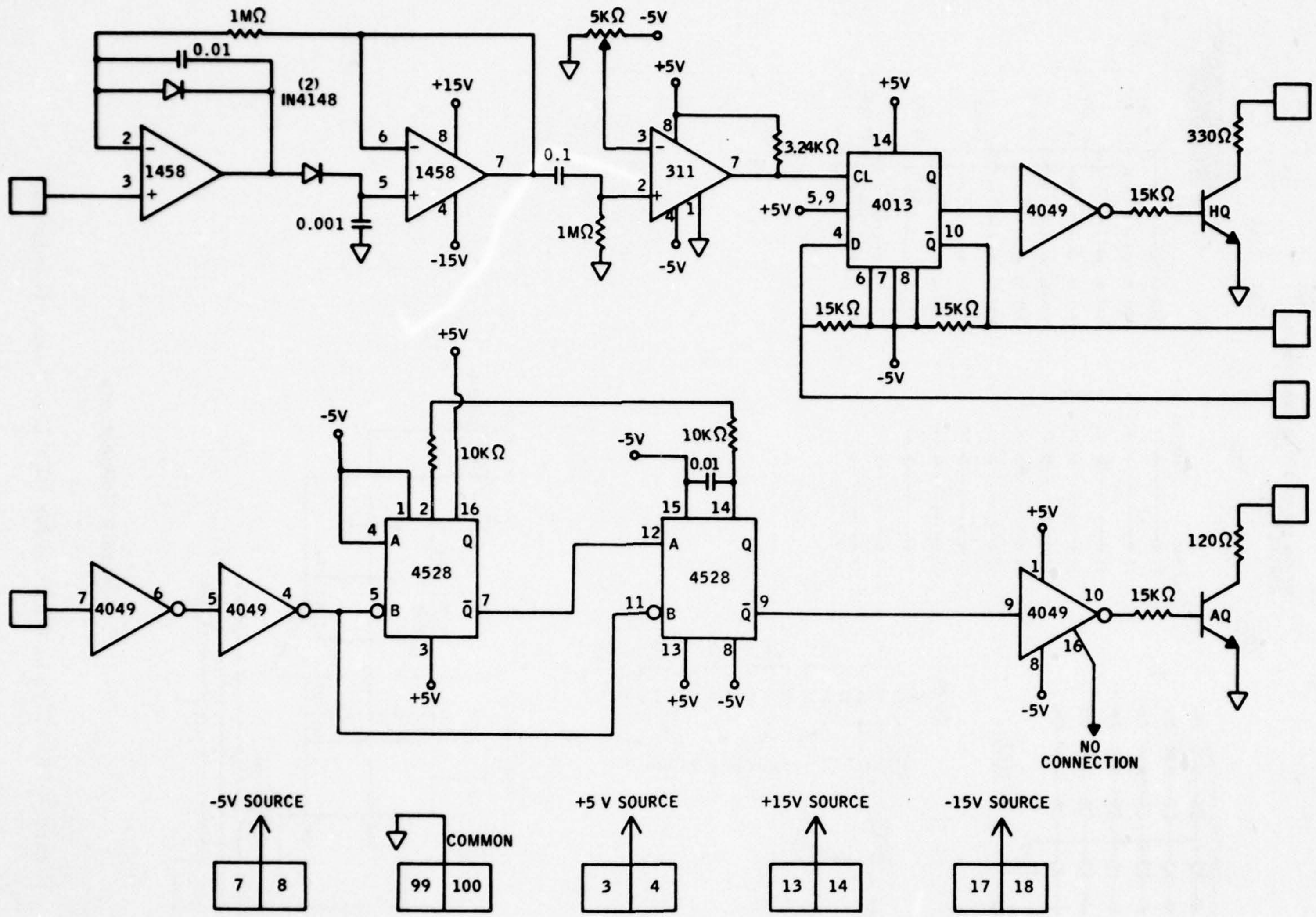


Figure 3-19. Life Test Console



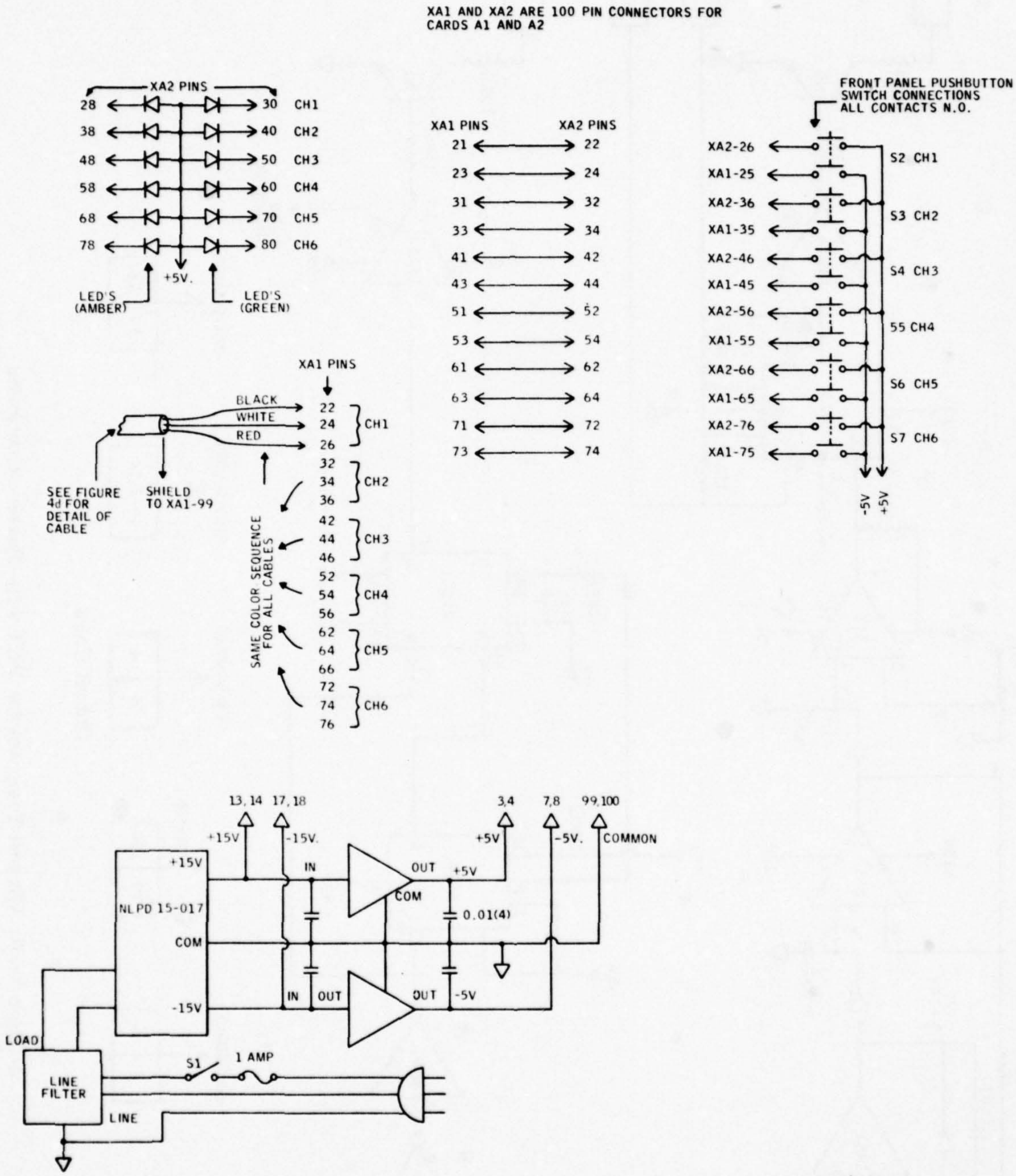
a. Input Card

Figure 3-20. Circuit Diagram for PET Life Tester



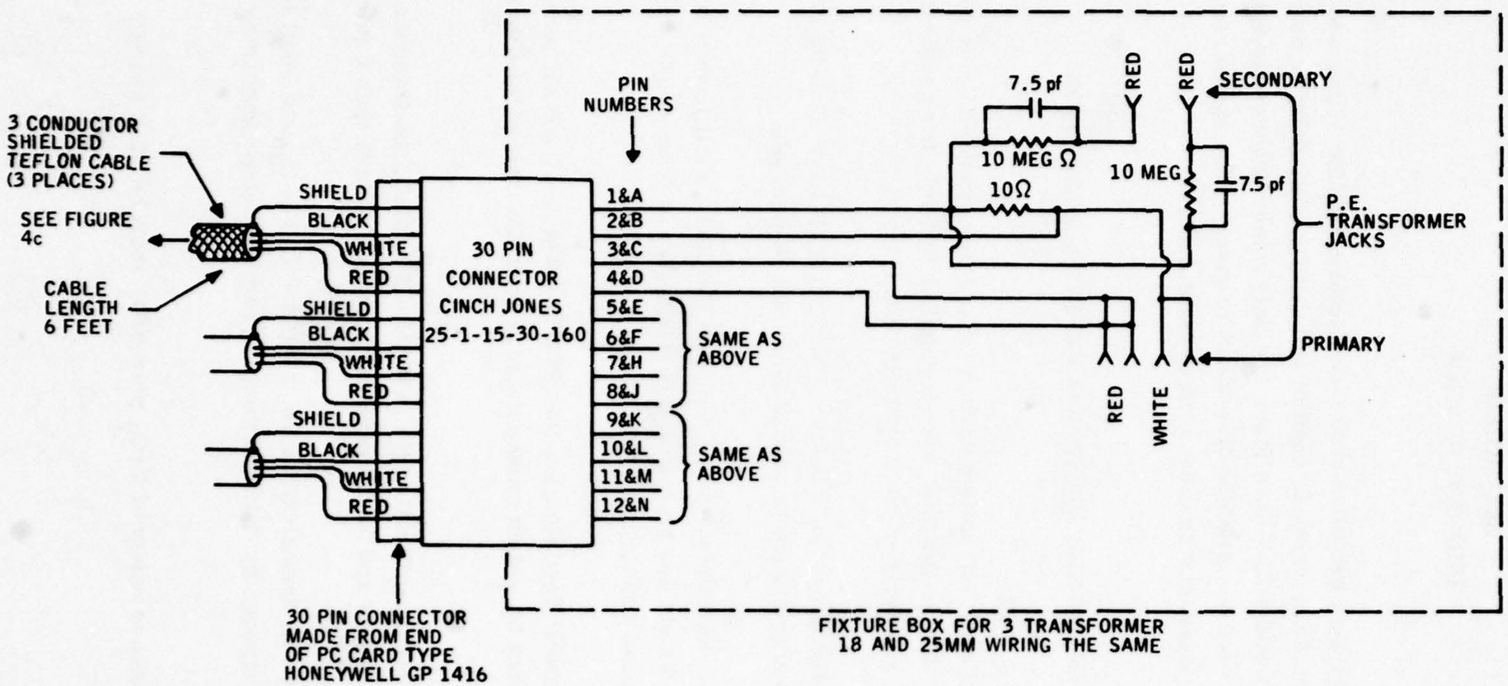
b. Output Card

Figure 3-20. Circuit Diagram for PET Life Tester (Continued)



c. Chassis Connections

Figure 3-20. Circuit Diagram for PET Life Tester (Continued)



d. Cable and Fixture

Figure 3-20. Circuit Diagram for PET Life Tester (Concluded)

SECTION IV
PROCESS REVIEW

This section reviews the process established to manufacture both the 18mm and 25mm PETs. Each major process step, process control and quality checkpoint is outlined for this process in Figures 4-1 and 4-2. Since there are only minor differences between the 18mm and 25mm process, only one process flow chart is given. The special tooling designed and built for this program was discussed in Section III.

A. MANUFACTURING PROCEDURE "A" FOR K-9 PZ-PT PREPARATION

The lead oxide, zirconia, titania, strontium carbonate and manganese dioxide used for the specific composition of this program have been used extensively for producing lead zirconate-lead titanate. A summary of each specification follows:

Lead Oxide (Honeywell Specification No. 27011) - The PbO shall have a purity of 99. 9 percent by weight and an average particle size of less than 10 microns.

Titanium Dioxide (Honeywell Specification No. 27018) - The TiO_2 shall have a purity of at least 99. 8 percent by weight and an average particle size of from 0. 5 to 3 microns. No single impurity may exceed 1300 p/m.

Strontium Carbonate (Honeywell Specification No. 27015) - The $SrCO_3$ shall have a purity of at least 99. 5 percent by weight and an average particle size of less than 6 microns.

Manganese Dioxide (Honeywell Specification No. 27059) - The MnO_2 shall have a purity of at least 99. 5 percent by weight and an average particle size of less than 6 microns.

Zirconium Dioxide - (Honeywell Specification No. 27001) - The ZrO_2 lots shall be selected for qualification purposes by the Honeywell Ceramics Center according to the following criteria:

a. The minimum combined purity of ZrO_2 plus HfO_2 shall be 99. 7 percent by weight.

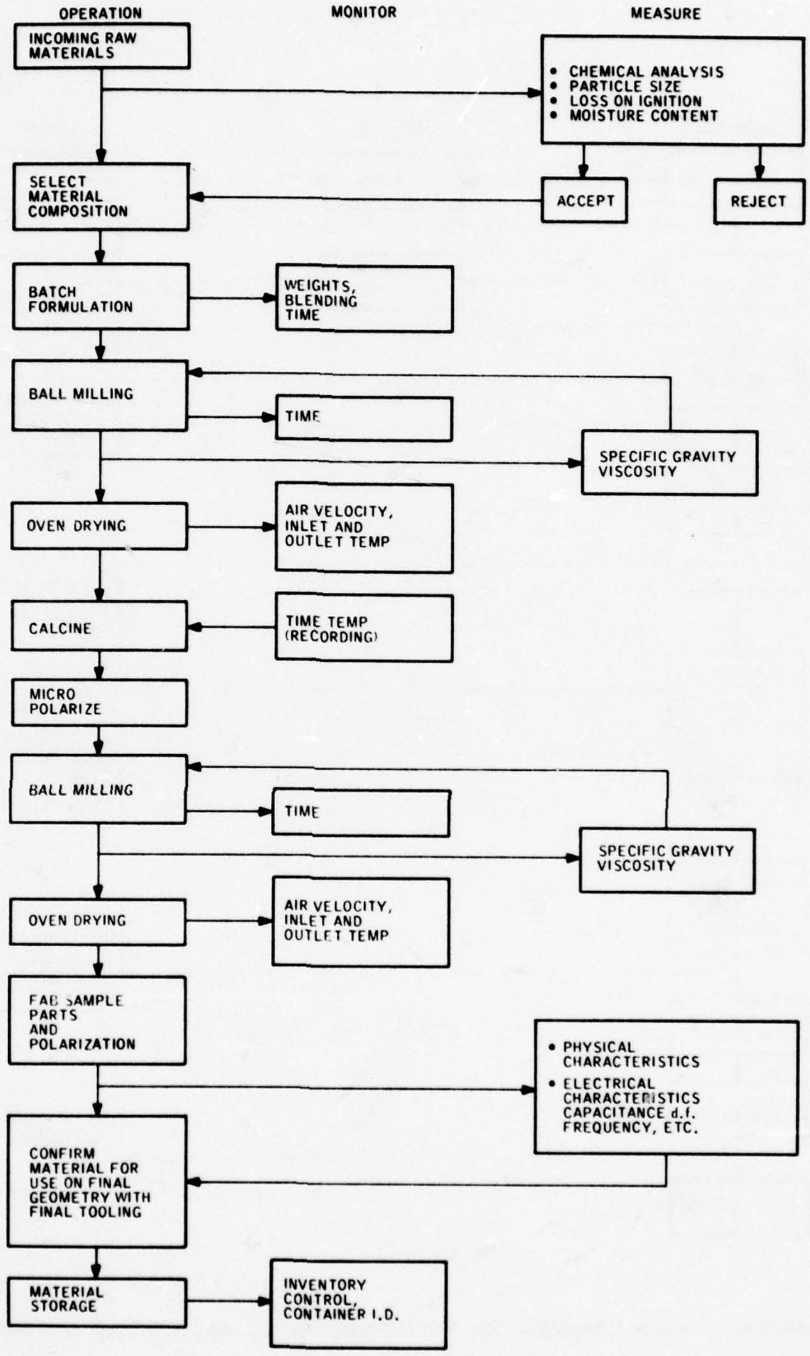


Figure 4-1. Flow Diagram for PET PZ-PT Raw Material Processing

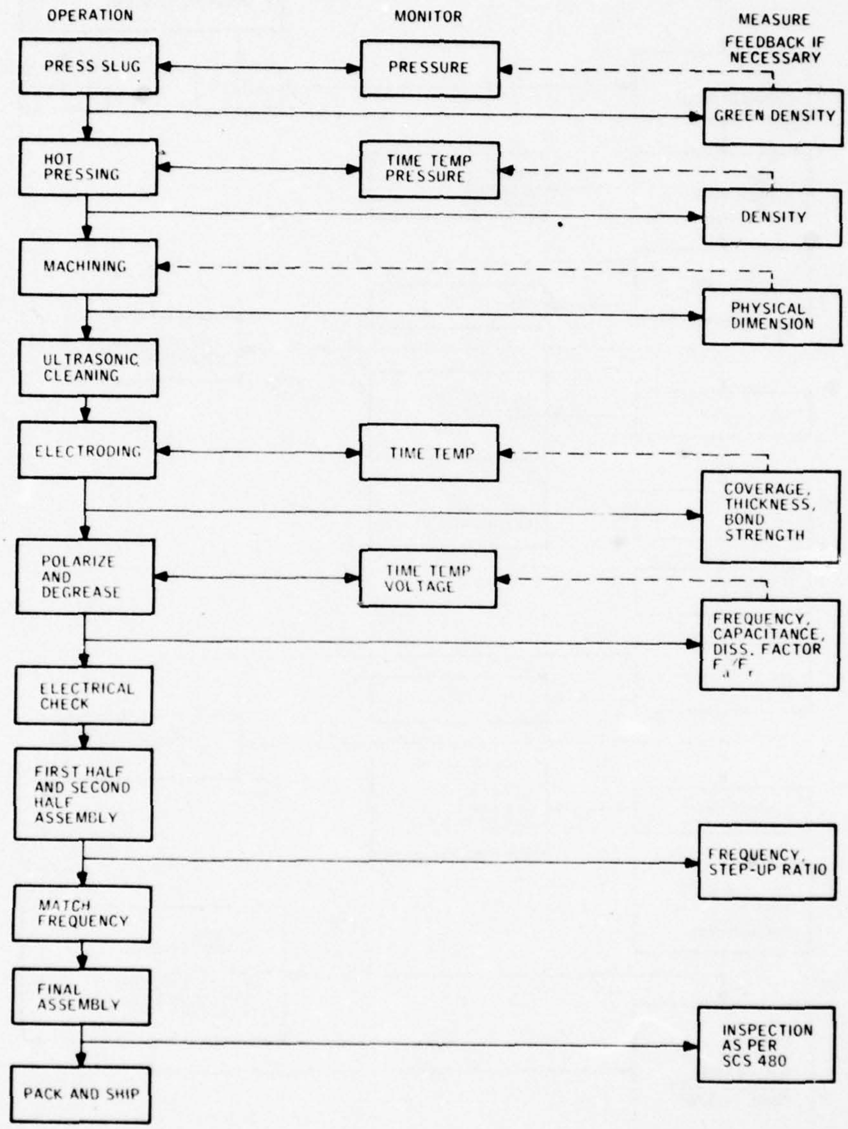


Figure 4-2. Flow Diagram for PET Fabrication and Packaged Assembly

b. Individual trace element impurities, except sodium and calcium, shall be less than 1300 p/m.

c. Sodium shall not be present in a concentration greater than 200 p/m.

d. Calcium shall not be present in a concentration greater than 400 p/m.

e. Particle size shall be less than 8 microns.

To qualify each raw material, a sample is submitted for a spectrographic analysis performed by the National Spectrographic Laboratory, 19500 South Mile Avenue, Cleveland, Ohio. The identity of the raw material, manufacturer, lot number and particle size for each lot of raw material is logged and records are kept for historical comparison. Particle size analysis is performed by Particle Research Lab., Division of Thermo-Systems, Inc., 2500 North Cleveland Avenue, St. Paul, Minnesota.

The approved sources for supply of these raw materials are:

Lead Oxide

Litharge Hammond Lead Products, Inc., 5231 Hohman Ave., Hammond, Indiana.

Eagle-Picher Industries Inc., American Building, Cincinnati, Ohio 45201.

Zirconium Oxide

Tizon Chemical Corporation, Flemington, New Jersey.

Harshaw Chemical Co., 1945 East 97th St., Cleveland, Ohio 44106.

Titanium Dioxide, Rutile

Whittaker, Clark and Daniels, Inc., West Broadway, New York City, New York.

N. L. Industries, Titanium Pigments Division, 111 Broadway, New York City, New York 10006.

Strontium Carbonate

J. T. Baker Chemical Co., Phillipsburg, New Jersey.

Manganese Dioxide

Mallenkrodt Chemical Works, St. Louis, Missouri.

Correction factors, below, are calculated for each raw material as applicable for use in batch formulation. Each raw material weight percent shall be multiplied by the appropriate correction factors to arrive at the corrected weight percents.

L. O. I. Correction Factors (C_L).

A loss-on-ignition (L. O. I.) correction factor shall be calculated once for each lot of each of the raw materials according to the following formula:

$$C_L = \frac{100}{(100 - Z)}$$

where Z is the weight percentage loss due to ignition, excluding free water loss. This is accomplished by heating a sample of approximately 10 grams at 1000 ± 20°C for approximately two hours.

Moisture Correction Factor (C_M).

A moisture correction factor shall be calculated for each raw material lot within 24 hours prior to material weighing. Correction factors shall be calculated according to the following formula:

$$C_M = \frac{100}{(100 - M)}$$

where M is the weight percentage loss due to heating a sample of approximately 10 grams at 150 ± 20°C for 12 hours minimum.

Purity Correction Factor (Cp).

A purity correction factor shall be calculated once for each lot of each of the raw materials according to the following formula:

$$C_p = \frac{100}{(100 - Y)}$$

where Y is the total percentage of impurities determined by converting the element impurity percentage obtained by spectrographic analysis to equivalent oxide (most common oxide) impurity percentages. Impurities listed in the analyses as below common detection limits shall be disregarded.

B. BATCH COMPOSITION

The nominal stoichiometric chemical composition of the PZ-PT batch selected for this program is

$$Pb_{0.94}Sr_{0.06}(Zr_{0.53}Ti_{0.47})_{0.99625}Mn_{0.005}O_3$$

Twelve batches of this composition were formulated from the specific materials given below in the requisite propostions after making the proper corrections. The values are transferred to a batch card in the general format given below:

Honeywell Spec.	Material	Vendor	Percent	Lot No.	Batch Wt. (gm)
27011	PbO	Hammond	65.243	2193	3914.58
27001	ZrO_2	Harshaw	20.233	068	1213.98
27018	TiO_2	WC&D	11.634	S072	698.04
27015	$SrCO_3$	Baker	2.755	400859	165.30
27059	MnO_2	Mallenkrodt	0.135	503	8.10
4528264	H_2O	Glenwood Ingl.	100%		6000 cc's

All raw materials were weighed on a Mettler shadowgraph scale to an accuracy of 0.1 gm and placed in a three-gallon polyethylene ball mill and mixed for two hours.

After mixing, the material was unloaded into stainless steel pans for drying. The material was dried for a minimum of 16 hours at 320°F in a Despatch drier and then cooled, removed, and crushed and blended in a polyethylene bag.

The blended materials were then placed in MgO saggers. The saggers were loaded into a Harper Kiln and calcined for five hours at a temperature of 900°C ± 10°F. After the material was calcined, it was placed in plastic bags, roller-pinned and then micropulverized to pass through a 12-mesh sieve. This material was then ball-milled in a polyethylene mill with 60 percent H_2O for two hours, dried and roller-pinned in a plastic bag.

C. MANUFACTURING PROCEDURE "B" FOR 18MM and 25MM PETS PRIOR TO PACKAGING

OP 010 Slug Processing

A. Materials Required

1. 1800 grams K-9 type PZ-PT Material

B. Tools and Fixtures

1. Hand Die 2-1/2-inch I. D. x 10-inch long
2. Knockout Punch
3. Denison Press (50 ton)
4. Vernier Calipers
5. 1800 gram volumetric gage

C. Procedure

1. Load material (1800 grams) into die. Place upper punch in sleeve and press to 15 tons pressure.
2. Eject slug from die and identify.
3. Check length - 4.8 ± 0.1 inches.

OP 020 Hot Press Slugs

A. Materials Required

1. MgO Sand

B. Tools and Fixtures

1. 4-inch O. D. x 2-1/2-inch I. D. x 7-inch long Alumina Die CGPT
2. Alumina Bottom Plate 4-inch diameter x 3/4-inch CGPT
3. Two Alumina Push Rods 2-1/4-inch diameter x 1-1/4-inch CGPT
4. Hot Press
5. 1240°C Temperature Cam

C. Procedure

1. Tape alumina plug in outer die. Pour a small amount MgO in bottom of die.
2. Place slug in mold and cover with additional MgO.
3. Center top spacer over slug.
4. Center three die sets in hot press and close press.
5. Heat to a temperature of 1240°C and pressure of 300 psig.
6. After hot press cycle is completed, open furnace, remove die sets, remove slugs, clean off excess sand and place slug in envelope with identification.

OP 030 Blanchard Grind Slugs (Top and Bottom)

A. Materials

1. 3M Tape, double sided

B. Tools and Fixtures

1. Steel Bars
2. No. 11 Blanchard Surface Grinder

C. Procedure

1. Tape face of Blanchard chuck.
2. Place slugs on the chuck and block in with steel bars.
3. Start grinder and remove 0.050 inch of material after a smooth surface has been obtained.
4. Remove slugs and repeat steps 1-3 for side two.

OP 040 Core Drill Slugs

A. Tools and Fixtures

1. Three Core Drills
   Sizes: 1-inch O. D.
   1-5/8-inch O. D.
   2-1/4-inch I. D.
2. Three Jaw Chuck
3. Gorton Vertical Mill

B. Procedure

1. Center slug in the three jaw chuck under the vertical spindle.
2. Start mill with 1-inch core drill and water coolant and core drill out of the smallest slug.
3. Repeat using 1-5/8-inch core drill.
4. Repeat using 2-1/4-inch core drill.
5. Save second slug for 18mm elements and third slug for 25mm elements. First slug and outer shell are scrap material.

OP 050 Hone I. D. of Slugs

A. Tools and Fixtures

1. Sunnen Hone
2. Mandrel 2GP28-1000 VA for 18mm
3. Mandrel 2GP28-1625 WD for 25mm
4. Truing Sleeves
5. Diamond Stones P28787
6. 1.040-inch and 1.700-inch Plug Gages

B. Procedure

1. Carefully true up hones on the machine with the truing sleeves.
2. Size inside diameters of slugs using very little pressure so as not to crack the slug.

   1.040 ± 0.001 inch for 18mm; 1.700 ± 0.001 inch for 25mm

OP 060 Grind O. D. of Slugs

A. Tools and Fixtures

1. Grinding Arbors
   18mm Dwg. No. 28100576-T1
   25mm Dwg. No. 28100571-T1
2. Brown and Sharp No. 1 Universal Grinder
3. 2-inch Micrometer
4. 3-inch Micrometer

B. Procedure

1. Place one to two 18mm or 25mm I. D. ground slugs on arbor and back up with spacers.
2. Place the arbor between centers of grinder.
3. Grind the O. D. diameter to 1.475 ± 0.001 inch for 18mm slugs or 2.100 ± 0.001 inch for 25mm slugs.
4. Remove and store for next operation.

OP 065 Slice 25mm Half Torroids

A. Materials

1. Do-All Mounting Wax
2. Mounting Blocks
3. Methyl Alcohol

B. Tools and Fixtures

1. Do-All Diamond Band Saw
2. 300°C Oven

C. Procedure

1. Heat 2.1-inch O. D. x 1.7-inch I. D. 25mm slug with a mounting block until mounting wax melts.
2. Mount base of slug to block and cool.
3. Mount block in band saw.
4. Slice slug to produce two (2) 1.000 ± 0.001-inch high toroids.
5. Reheat to melt wax and demount.
6. Cool and clean off excess wax in methyl alcohol.

OP 070 Mount and Slice Slugs

A. Materials

1. P. C. Slurry mix with No. 600 boron carbide
2. Mounting Pad

B. Tools and Fixtures

1. Varian 686 Slicing Machine
2. Blade Package 0.008 x 1/4-inch blades with 0.013-inch thick spacers

C. Procedure

1. Mount slugs on submount base with wax.
2. Place slurry mix in the wafering machine.
3. Mound sub-base on machine.
4. Properly tension blade package.
5. Slice slugs into 0.010 ± 0.0005-inch thick elements.
6. Demount in alcohol.
7. Pack and ship.

OP 080 Clean Elements

A. Materials

1. Detergent
2. Chlorethene
3. Alcohol
4. Plastic tray

B. Tool and Fixtures

1. Ultrasonic Cleaner

C. Procedure

1. Unpack parts and place in a plastic tray.
2. Ultrasonic clean in chlorethene.
3. Ultrasonic clean in detergent solution.
4. Rinse in water.
5. Rinse in alcohol.

OP 090 Inspection of Unelectroded 18mm and 25mm Elements

Inspect sample of parts for mechanical size per drawing No. 28100576 or 28100571, respectively.

OP 100 Apply Silver Electrodes

A. Materials

1. Silver Electrode Paste
2. Ethyl Acetate cleaning solvent

B. Tools and Fixtures

1. Screen Printer
2. Silk screen frame; 18mm, 25mm Dwg. No. 28100576-T2, 28100571-T2
3. Nests; 18mm, 25mm Dwg. No. 28100576-T3, 28100571-T3
4. 300°C oven

C. Procedure

1. Mount silk screen frame in printer and center pattern.
2. Condition screen with silver paste.
3. Place clean parts, 5-18mm or 6-25mm in nest.
4. Mount nest in printer.
5. "Squeegy" silver paste on side one.
6. Remove nest and place parts in drier for curing.
7. Cool parts, reverse and do side two as in steps 3-6, above.

OP 110 Silver Fire

A. Tools and Fixtures

1. Belt Furnace (2000°F)
2. Setter plates 6 inches x 4 inches x 1/2 inch

B. Procedure

1. Place parts on setter plates.
2. Place plates on belt of furnace - temperature set at 1640°F.
3. Remove cooled parts and store.

OP 120 Polarization

A. Materials

1. Peanut Oil

B. Tools and Fixtures

1. 30 kV polarization station, per Drawing No. 28100576/1-T4 and T6

2. Poling fixture, per Drawing No. 28100576/1-T5

3. Chlorethane degreaser

C. Procedure

1. Place 18mm or 25mm elements in poling fixture with positive and negative leads of primary electrodes connected to external leads.

2. Rotate fixture in 165°C oil bath to next station. Voltage is applied to parts in oil.

3. Apply 1500 volts to primary and 16.5 kV to 18mm, or 27 kV to 25mm secondary electrodes.

4. Repeat steps 1-3.

5. Degrease part in chlorethane.

6. Mark polarity

7. Store parts for next stage.

OP 130 Check Polarity

A. Tools and Fixtures

1. d_{33} Checker

2. Sample Holder

3. Frequency Bridge

B. Procedure

1. Place part in sample holder

2. Scan resonant and antiresonant frequency for fa, fr and fa/fr between primary electrodes.

3. Repeat for secondary segments of element.

4. Insert part in d_{33} Checker and check polarity per drawing 28100510 and 28100571, respectively.

D. MANUFACTURING PROCEDURE "C" FOR INJECTION MOLDING OF 18MM and 25MM CASES

OP 010 Molding of 18mm or 25mm Cases (New)

A. Material

1. Nichols Well-A-Meld G25-15-66 (6/6 nylong with glass fibers and spheres)

B. Tools and Fixtures

1. Arburg 200 Injection Press
2. Universal Chase for above press
3. Mold 18mm (Dwg. No. 281100580/1-T1) or 25mm (Dwg. No. 28100574/5-T1)
4. Inserts for mold with knock out plate and pins
5. Vacuum oven with temperature controller or thermometer
6. Pans for driving material (1-pound cake pans)
7. Mold Heater
8. Side cutter for plastics

C. Mold Set-up

1. Attach universal chase outer plates to the appropriate sides of press platens.
2. Install mold cavities into the chase inner plates.
3. Secure with backing plates.
4. Slide chase inner plates into tracks provided for same on the outer plates that are mounted in press.
5. Snug all outer bolts and clamp bolts just fingertight.
6. Be sure press speed is throttled back (reduced) and close press, engaging the two halves of the mold.
7. With mold in this position, tighten all clamps and bolts. Mold is then aligned.
8. Installation of sprue bushing and knock out pin adjustment is done at this time.
9. Hook up hoses to fixtures on the bottom of the inner plates. These go to the mold heater.

10. Turn on mold heater and set to desired temperature.

11. Set press to the following readings:

Nozzle:	530°F
Front:	500°F
Center:	500°F
Rear:	490°F
Mold Temp:	
Top:	120°F
Bottom:	120°F
Inj. Press:	4000 psi
Inj. Timer:	12 seconds
Clamp Timer:	22 seconds
Speed	5
Feed Rod:	2 inches
Back Press:	0
Mold Release:	MS122 at startup
Mach. Type:	Arburg 200

D. Procedure

1. Dry material in cake pans (approximately 12 x 18-inch) about 1 inch deep for 2 to 4 hours at 170°F.
2. Place into machine hopper in airtight compartment.
3. After purging material out of barrel, start machine into its semi-automatic stage and start to operate.
4. Do not overpressure parts as this can shear all of the 0.020 pins in the mold.
5. Remove parts straight out to clear these same pins. If parts are taken off by rolling, pins could be broken.

OP 020 Gate Removal of 18mm and 25mm Cover and Case

A. Tools and Fixtures

1. Sheldon Lathe
2. Step Collet
3. Cutting Tool

B. Procedure

1. Place part in lather.
2. Set speed of lathe at 300 rpm.
3. Machine off gate.
4. Deburr sharp edges.
5. Remove part and store

E. MANUFACTURING PROCEDURE "D" FOR PACKAGING 18 and 25MM PETS

OP 140 PET Package Preparation, 18mm

A. Materials

1. Package Case - Top, Dwg. 28100580
2. Package Case - Base, Dwg. 28100581
3. Terminals, Dwg. 28100572
4. Silicone Pads
5. 18mm Shorting Straps - Top, Dwg. 28100579
6. 18mm Pins, Dwg. 28100570-002
7. TF Freon
8. Marking Ink P-12
   Automated Packaging System
9. Marken Printing Machine

B. Tools and Fixtures

1. Staking Tool, 18mm
2. Arbor Press, 18mm
3. Staking Fixture

(Items 1–3: Dwg. 28100577-T1)

4. Pliers
5. Knife
6. No. 76 Carbide Drill
7. High Speed Drill Press
8. Ultrasonic Cleaner
9. Rubber Stamps, Dwg. 28100577-T2 and 3

C. Procedure

1. Debur holes and edges of case top and case base.
2. Place terminal pin in fixture.
3. Place top shorting strap over pin and then put top case over pin and strap.
4. Stake pin firmly to case.
5. Repeat Steps 1 and 3 for each hole in case.
6. Drill 0.020-inch diameter holes as shown in Dwg. 28100577.
7. Ultrasonic clean case top and case base in freon.
8. Cut and place mounting pads in case top and case base at locations shown in Dwg. 28100577 and Dwg. 28100578.
9. Using Marken Printing Machine and rubber stamps, stamp terminal identification, date code, part nunber and serial number as shown in Dwg. 28100577.

OP 145 PET Package Preparation, 25mm

A. Materials

1. Package Case, Top - Dwg. 28100574
2. Package Case, Base - Dwg. 28100575
3. Terminals, Dwg. 28100572
4. Silicone Pads
5. P-Terminal Pin - Dwg. 28100570-003
6. 25mm Shorting Straps - Top, Dwg. 28100573
7. 25mm Pins - Dwg. 28100570-001
8. TF Freon
9. Marking Ink P-12
   Automated Packaging System
10. Markin Printing Machine

B. Tools and Fixtures

1. Staking Tool, 25mm
2. Arbor Press, 25mm

   Dwg. 28100569-T1

3. Staking Fixture
4. Pliers

5. Knife

6. No. 76 Carbide Drill

7. High Speed Drill Press

8. Ultrasonic Cleaner

9. Rubber Stamps { Dwg. 28100569-T2
Dwg. 28100577-T3 }

C. Procedure

1. Debur hole and edges of case top and case base

2. Place Terminal pin in fixture

3. Place top shorting strap over pin and then put top case over pin and strap.

4. Stake pin firmly to case

5. Repeat steps 1 and 3 for each hole in case

6. Drill 0.020-inch diameter holes as shown in Dwg. 28100569

7. Ultrasonic clean case top and case base in freon

8. Cut and place mounting pads in case top and case base at locations shown, Dwg. 28100569 and Dwg. 28100568

9. Using Marken Printing Machine and rubber stamps, stamp terminal identification, date code, part number and serial number as shown in Dwg. 28100509.

OP 150 Top Case Element Assembly

A. Materials

1. Solder flux (Kester 1544)

2. Solder (Kester Flux 44 Resin Core - 0.030-inch dia.)

3. Gold Wire 0.005-inch x 0.015-inch x 0.7-inch

B. Tools and Fixtures

1. 18mm Alignment Fixtures "A" and "B" Dwg. No. 28100560-71

2. Solder Iron (25 watt)

3. Variac (5 amp)

4. Tweezers

5. Snips

C. Procedure

1. Place element in 18mm alignment fixture "A" with positive side of primary electrodes down.

2. Line up secondary stripes with V_{12} and V_3 slots (either stripes OK) and apply very light coating of flux on V_{12} V_3 and two primary electrode areas.

3. Lay gold ribbon lead on fluxed area and alignment slots V_{12} and solder ribbon in place with a minimum amount of solder but cover gold lead. Repeat for V_3 and two primary leads on negative side.

4. Remove element, turn over and place in Fixture "B" with positive primary electrodes up.

5. Preflux two areas on positive electrode and solder gold ribbon leads to these areas.

6. Remove and clean soldered areas with Clorathine.

7. Bend all leads on first side to about 90° and insert these through the holes in the top case.

8. Use tweezers to pull excess lead through the case and solder to shorting bar. Leave small stress loop in gold ribbon to allow for the movement while heating.

9. Use tweezers to feed two positive leads between silastic pads and case through hole and solder to center of shorting bar.

OP 155 Procedure for 25mm similar to that above except follow approach described on Dwg. 28100561.

OP 160 Process and Control Electrical Check

A. Tools and Fixtures

1. Automatic Test Console - Dwg. 28100560-T2
2. Terminal Boxes (18mm) - Dwg. 28100560-T3 and T4
3. Terminal Bixes (25mm) - Dwg. 28100561-T2 and T3

B. Procedure

1. Insert top PET case into terminal box

2. From test console record resonant frequency, input voltage, input current and output voltages on data sheet and check against the room temperature requirements on Dwg. 28100560 or 28100561.

OP 170 Final Package Assembly

A. Tools and Fixtures

1. Pliers
2. Solder iron
3. Snips

B. Procedure

1. Select a top case assembly, Dwg. 28100577 or 28100567, and a base case (Dwg. 28100578 or 28100568); then align shorting pins from base case with holes in top case.
2. Gradually force each of the 12 pins through holes in package and shorting strap with pliers.
3. After all pins have been inserted in the package and it is fully closed, snip off excess pin length and solder to shorting strap.
4. Check electrical properties on test console and record data on data sheet.

OP 180 Final Inspection

Inspect packaged 18 or 25mm piezoelectric transformers per Dwg. 28100560 or 28100561, respectively.

SECTION V
SPECIFICATION AND INSPECTION PROCEDURES

This section reviews the specification established for 18mm PETs and the testing and inspection procedures established for this purpose.

A. SPECIFICATION

Appendix A gives the specification which defines the requirements and quality assurance provisions for PETs. The specification requires a hot pressed PZ-PT because this type of material is the only material which has been shown to have sufficient temperature stability, thin film (0.010 inch) uniformity and physical strength to meet the requirements of this specification.

Initially, the thermal shock requirement was a particularly difficult requirement to meet with the bonded set of four 25mm elements used in the second engineering sample build or even the two bonded pair of 25mm elements used in the first engineering and confirmatory sample builds. If future multiple element PETs are designed, bonding with a more pliable media such as silicone rubber would probably be more suitable than the rigid epoxy bonds. All pilot production 18mm units satisfactorily meet the thermal shock requirements.

Humidity and barometric pressure requirements were eliminated because the packaged PETs are intended to be potted with the other power supply components. Therefore, these tests have no meaning for the unpotted PETs. Both of these requirements were evaluated on the engineering samples and no operational or physical damage was caused by these tests.

All other specification requirements were readily met.

B. INSPECTION PROCEDURE

The inspection procedures used for the 18mm elements are given in the following pages of this section. While no detail is given for the 25mm PET parts, the procedure was identical with suitable substitution of the 25mm drawing requirements.

The first procedure for the unpoled and poled 18mm element, part number 28100576, was used with Manufacturing Procedure "B" in Section IV. The next two procedures for the 18mm case, part numbers 28100577 and 28100578, were used with Manufacturing Procedure "D". The last procedure was used for final quality conformance evaluation of the completed 18mm pilot production PET units.

INSPECTION PROCEDURE

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	090 - S	18MM - Unelectroded	28100576		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
	HANDLE PARTS CAREFULLY as they are very fragile					
A	VISUAL					
	1.0 Cracks - Parts shall be free of cracks & laminations		A	.25	Visual 10X	
	2.0 Voids – Parts shall have no voids larger than .020 dia.		A	.25	Visual 10-30X	
	3.0 Edge chips from which a crack can propagate shall be cause for rejection. 		B	.65	Visual 10X	
B	Dimensional					
	1.0 Thickness .010 ± .001		B	.65	UG76	
	2.0 OD 1.475 ± .001 dia.		B	.65	UG312D6 Go - No Go	
	3.0 ID 1.040 ± .001 dia.		B	.65	UG312D6 Go - No Go	
C	Disposition					
	1.0 Record Inspection results on QDR #1 and sign off flow ticket as required. If the lot is rejected, initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1-31-78	Ripley	JS				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R. Ripley	12-20-76	28100562		

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	130 - S	18MM - Element Poled	28100576		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	VISUAL					
	1.0 Parts shall be free of contimination and foreign material and shall show no visible signs of having been arced.		B	.65	Visual - 7X	
	2.0 Parts shall be free of cracks.		A	.25	Visual - 10X	
	3.0 Parts shall have no chips which protrude into the electrode.		A	.25	Visual - 10X	
	4.0 Electrode voids - There shall be no more than three per surface when between .010 and .030. None allowed larger than .030.		B	.65	Visual - 7X 30X for measure	
B	DIMENSIONAL					
	1.0 Center electrode bands shall be .080 ± .010 wide.		C	1.0	Visual - 30X w/reticule	
	2.0 Electrode spacing shall be .270 ± .010 (4 plcs. both sides).		C	1.0	Visual - 10X w/reticule (reading X3)	
	3.0 Electrode borders shall be .005 to .020 (large electrodes 4 plcs.)		B	.65	Visual - 30X w/reticule	
C	ELECTRICAL					
	1.0 Polarity - parts shall exhibit positive polarity with polarity mark "up"		A	.25	Berlincourt D_{33} Tester with button anvil on bottom	
	2.0 D_{33} - Each large electrode when centrally positioned shall read 200×10^{-12} coul/newton minimum.		B	.65	Berlincourt D_{33} Tester w/button anvil on bottom.	

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
1	1-14-77	Ripley					

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET	AY28100576	1	33

WRITER	DATE	PART NUMBER	REV	MOD
R. Ripley	1-14-77	28100560		

INSPECTION PROCEDURE

HONEYWELL INC.

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	130 - S	18MM - Element - Poled	28100576		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
D	RECORDS 1.0 Record Inspection results on QDR #1 and sign off flow tickets. If the lot is rejected, initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
1	1-14-77	Ripley	JSE				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET	AY28100576	1	33

WRITER	DATE	PART NUMBER	REV	MOD
R. Ripley	1-14-77	28100576		

INSPECTION PROCEDURE

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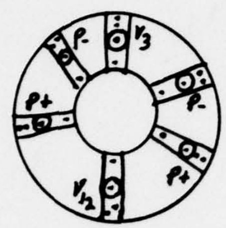
INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	140 - S	18MM - CASE, TOP WITH PADS	28100577		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A.	VISUAL					
	1.0 Presence of silastic pads (6 places) and shall not be sticky. Parts shall be relatively free of excess silastic.		C	1.0	Visual	
	2.0 Presence of silastic primer - as viewed from bottom of case, there shall be a reddish color at the pad positions.		C	1.0	Visual	
	3.0 Transfer Tape 3 plc (approx. 120° apart) 0.080 overall height from bottom of case to top of tape.		C	1.0	Visual	
B.	DIMENSIONAL					
	1.0 Silastic pad height -.005 to .015		B	.65	G158 .001 Dial Ind.	
C.	MARKING					
	1.0 Marking shall be as shown: (black ink)		B	.65	Visual	
D.	RECORDS					
	1.0 Record Inspection results on QDR #1 and sign off flow tickets. If parts are rejected, initiate MAR.					



ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
1	1-20-78	Ripley	Lee				
2	1-30-78						

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R. Ripley	1-20-78	28100574		

INSPECTION PROCEDURE

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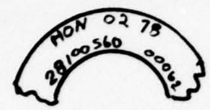
INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	140 - S	18MM - Case, Base with Tape Pads	28100578		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	VISUAL					
	1.0 Presence of silastic pads - Parts shall be relatively free of excess silastic and shall be cured (not sticky).		C	1.0	Visual	
	2.0 Presence of Primer - As viewed from Bottom of the case, a reddish color should be present at each pad position.		C	1.0	Visual	
B	DIMENSIONAL					
	1.0 Silastic Pads - .005 to .015 high.		B	.65	.001 Dial Ind. w/pointed tip G158	
	2.0 Transfer Tape - (3 plcs.) (120° apart) .080 max. (Top of tape to bottom of case.)		B	.65	UG312D6	
C	MARKING					
	1.0 The parts shall be marked as shown: HON, week poled, year, part number and S/N.		B	.65	Visual	
D	RECORDS					
	1.0 Record Inspection results on QDR #1 and sign off flow tickets. If the lot is rejected, initiate an NMAR.					



ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
1	1-20-77	Ripley	Sa				
2	1-31-78						

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R. Ripley	1-20-77	28100578		

INSPECTION PROCEDURE

HONEYWELL INC.

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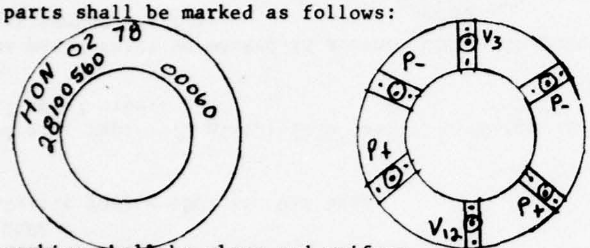
INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "A" 18MM - Workmanship	28100560		

ITEM NO.	CHARACTERISTIC	CD	AQL	EQUIP	REF
A.	VISUAL				
	1.0 Case shall be free of cracks.	A	.25	Visual 10X	
	2.0 Pins shall be free of loose burrs.	A	.25	Visual 10X	
	3.0 Gold plated pins and shorting bars shall show no evidence of plating blisters or peeling.	A	.25		
	4.0 Solder joints shall be free of peaks and shall be of good quality.	A	.25	Visual 10X	
	5.0 Case shall exhibit no gaps at the sides between top and bottom covers.	A	.25	Visual 10X	
B.	PRINTING				
	1.0 The parts shall be marked as follows:	A	100%	Visual	
	2.0 The marking shall be clear and uniform.	A	100%	Visual	
C.	DIMENSIONAL				
	1.0 Stack height shall be .025 ± .005	A	.25	UG312D6	
	2.0 O.D. 1.575 ± .005	A	.25	UG312D6	
	3.0 I.D. .940 ± .005	A	.25	UG312D6	



ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1-27-78	Ripley	Jbr				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R. Ripley	1-20-78	28100560		

INSPECTION PROCEDURE

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	GROUP "A" 18MM - WORKMANSHIP	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
D.	ASSEMBLY WEIGHT					
	1.0 The assembly shall weigh less than 5.0 grams.		C	4.0	Satorous Bal.	
E.	DISPOSITION					
	1.0 Record Inspection results on QDR #1 and sign off data sheet as required. If the lot is rejected, initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1-27-78	Ripley	SSC				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R. Ripley	1-20-78	28100560		

INSPECTION PROCEDURE

HONEYWELL INC.

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	18mm - GROUP "A" THERMAL SHOCK	28100560		

ITEM NO.	CHARACTERISTIC	CD	AQL	EQUIP	REF
A.	Thermal shock 1.0 Each PET shall be subjected to five thermal shock cycles. Seperate temperature chambers shall be used for hot and cold and transfer time shall be less than one minute between temperatures. The temperature and duration of each cycle are as follows:	A	.65	Hafstrom environmental chambers and shock fixtures	

Cycle #	+68°C + 3°C - 0°C 15 minutes		25°C + 10°C - 5°C 1 minute	-57°C + 0°C - 5°C 15 minutes	
1	in	out	"	in	out
2	in	out	"	in	out
3 etc	in	out	"	in	out

2.0 Complete temperature shock data sheet and file in lot folder.

B. Disposition
1.0 Record inspection results in QDR#1 and proceed to next inspection operation.

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/27/78	Ripley Jr.					

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560		

INSPECTION PROCEDURE

HONEYWELL INC.

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	18mm GROUP "A" THERMAL SHOCK	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A.	Visual					
	1.0 Parts shall be free of cracks.	A		.65	Visual 10X	
	2.0 Solder joints shall not be cracked.	A		.65	Visual 10X	
	3.0 Case sides shall exhibit no gaping at seams.	A		.65	Visual	
B.	Electrical @ (2.5 V Peak) (Record)	A		.65	Pet tester	
	1.0 Resonant frequency - 32.3 $\pm$ 1.6 KHZ.				Cap. bridge	
	2.0 Read and record current and V12, V3 voltages.				Calculator	
	3.0 Efficiency total at resonance $\dfrac{\dfrac{V12^2}{2\times10^6} + \dfrac{V3^2}{100\times10^6}}{V\ in \quad I\ in} \times 100 = 30\%$ minimum					
	4.0 Step up voltages - $\dfrac{V12}{2.5} = 107 \pm 27$; $\dfrac{V3}{2.5} = 173 \pm 43$					
	5.0 Primary capacitance - 14.0 $\pm$ 1.4 nf.					
	6.0 Primary dissipation - 1.5% max.					
	7.0 Secondary capacitance - 10 pf max. (2)					
	8.0 Secondary dissipation - 1.5% max. (2)					
	9.0 Induced voltage - slowly increase input voltage to 3.75 volts peak and monitor pet 1 and pet 2 lights for signs of arcing or erratic current for a period of 5 seconds $\pm$ 1/2.					
C	Terminal strength (1/2 lb. force)					
	1.0 Examine pins for looseness after completion of electrical tests.	A		.65	Visual 10X manual	

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/27/78	Engly Sez					

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
pet		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560		

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	'80 - S	GROUP "A" 18mm - POST THERMAL	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
E	Disposition 1.0 Record inspection results on QDR#1 and complete all data sheets. Submit data to quality engineering for calculations and disposition of all rejected units.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/27/78	R. Ripley					

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
pet		1	33

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560		

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PRODUCTION ENGINEERING MEASURE (PEM) MANUFACTURING METHODS AND --ETC(U)
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INSPECTION PROCEDURE

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup 1 18 MM - Temperature Storage	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	High temperature storage 1.0 The units shall be stored for a minimum of 8 hours at + 71°C $\pm$ 2°C	A		12 pcs	Environmental chamber & pet tester	
	2.0 The units shall then gradually be lowered to + 52°C and stabilized for 30 minutes and tested for the following electrical characteristics @ 2.5 V peak. a. Resonant frequency - 32.5 $\pm$ 1.6 KHZ b. Record V12 and V3 voltages c. Record input current d. Calculate overall efficiency - 30% minimum. e. Voltage step up ratio $\frac{V12}{2.5} = 107 \pm 27$ f. Voltage step up ratio $\frac{V3}{2.5} = 173 \pm 43$					
B	Low temperature storage 1.0 The same units tested in A above shall be stored for a minimum of 2 hours at -65°C $\pm$ 2°C. The temperature shall then be gradually raised to -52°C $\pm$ 2°C and stabilized for 30 minutes and tested for the following electrical characteristics at 2.5 volts peak. a. Resonant frequency - 31.6 $\pm$ 1.6 KHZ b. Record V12 and V3 voltages c. Record input current d. Calculate overall efficiency - 15% minimum e. Voltage step up ratio $\frac{V12}{2.5} = 58 \pm 14$ f. Voltage stepup ratio $\frac{V3}{2.5} = 90 \pm 18$	A		12 pcs	Environmental chamber & pet tester	

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/27/78	Ripley	Kez				

DEVICE NUMBER	SPECIFICATION	DATA REC NO	SAMPLING PLAN NO
PET		1	SP

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560	-	

INSPECTION PROCEDURE

HONEYWELL INC.

DIST.

INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup 1 18MM - Temperature Storage	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
C	Disposition 1.0 Record inspection results on QDR#1 and file data in lot folder. If sample is rejected initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/27/78	[signature]	[signature]				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	SP

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560		

INSPECTION PROCEDURE

HONEYWELL INC.

HI-10 REV.3 6/70

DIST.

INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup - 2 18MM - Mechanical Vibration	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	Vibration 1.0 Subject samples while under power to a harmonic vibration motion parallel and perpendicular to the radial axis over a frequency range of 10HZ to 55 HZ at a constant 2.5 g for a period of two minutes in each axis, one minute duration each cycle.	A		20 pcs	Vibration hopkins vibration fixture-life test monitor Dwg. No. 28100560-T5, 6	4.5.11
B	Electrical @ 2.5 peak (post vibration) 1.0 Resonant frequency - 32.3 ± 1.6 KHZ 2.0 Record V12 voltage 3.0 Record V3 voltage 4.0 Record input current 5.0 Overall efficiency - 30% minimum 6.0 Voltage stepup V12 and V3 107 ± 27 and 173 ± 43	A		20 pcs	Pet tester Dwg. No. 28100560-T2, 3 & 4	
C	Disposition Record inspection results on QDR#1. If sample is accepted proceed with mechanical shock test. File data in lot folder. If sample is rejected initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/30/78	R.Ripley [signature]					

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	SP

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560		

INSPECTION PROCEDURE

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DIST.

INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup 2 18MM - Mechanical Shock	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	Shock 1.0 Rigidly mount the transformer and shock in a plane vertical and then parallel to the radial axis at 310g's minimum for a duration at .10 ± .05 milliseconds for three pulses.	A		20 pcs	Shock machine Hopkins Dwg. No. 28100560-T6	4.5.12
B	Electrical @ 2.5V peak (post vibration) 1.0 Resonant frequency - 32.3 ± 1.6 KHZ 2.0 Record V12 voltage 3.0 Record V3 voltage 4.0 Record input current 5.0 Overall efficiency - 30% minimum 6.0 Voltage step ratio V12 and V3 - 107 ± 27 and 173 ± 43 7.0 Induced voltage - slowly increase voltage to 3.75 volts peak and monitor parts for evidence of arcing or erratic current.	A		20 pcs	Pet tester Dwg. No. 28100560-T2, 3 & 4	
C	Disposition Record inspection results on QDR#1. File data in lot folder. If sample is accepted sign off flow ticket as required. If sample is rejected initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/30/78	Ripley Lee					

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	sp

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560		

INSPECTION PROCEDURE

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INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup 2 18MM - Mechanical Shock	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	Shock 1.0 Rigidly mount the transformer and shock in a plane vertical and then parallel to the radial axis at 310g's minimum for a duration at .10 ± .05 milliseconds for three pulses.	A		20 pcs	Shock machine Hopkins Dwg. No. 28100560-T6	4.5.12
B	Electrical @ 2.5V peak (post vibration) 1.0 *Resonant frequency* - 32.3 ± 1.6 KHZ 2.0 Record V12 voltage 3.0 Record V3 voltage 4.0 Record input current 5.0 Overall efficiency - 30% minimum 6.0 Voltage step ratio V12 and V3 - 107 ± 27 and 173 ± 43 7.0 Induced voltage - slowly increase voltage to 3.75 volts peak and monitor parts for evidence of arcing or erratic current.	A		20 pcs	Pet tester Dwg. No. 28100560-T2, 3 & 4	
C	Disposition Record inspection results on QDR#1. File data in lot folder. If sample is accepted sign off flow ticket as required. If sample is rejected initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/30/78	Ripley	See				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	sp

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560		

H1-10
REV. 3
6/70

INSPECTION PROCEDURE

HONEYWELL INC.

DIST.

INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup 3 18mm - LIFE TEST	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	Life test (500 hrs) 1.0 Randomly select acceptable units from the lot and put into life test fixtures. 2.0 Turn on life test fixtures and press reset buttons for each station. Green lamps shall light. 3.0 Set oven temperature for 52 ± 2°C. 4.0 Periodically monitor test box for yellow lamps being lighted. (notify quality engineer if yellow lamp(s) light)	A		9 pcs	Life tester Dwg. No. 28100560-T5	
B	Periodic testing(@ 96 hrs and 240 hours) 1.0 Record secondary voltages, V12 and V3, at 96 hours and 240 hours.					
C	Disposition - Record inspection results on QDR#1 and submit test data to Quality Engineering for calculations. File data in lot folder. If sample is rejected initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1-30-78	[signature]	[signature]				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	SP

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560	-	

INSPECTION PROCEDURE

HONEYWELL INC.

HI-10
REV.3
6/70

DIST.

INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup 3 18MM - POST LIFE TEST	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
	After 500 hrs. of operation at 52 ± 2°C remove units and allow to come to room temperature and stabilize for 24 hrs.					
A	Post life - electrical tests (@ 2.5 V peak)					
	1.0 Resonant frequency - 32.3 ± 1.6 KHZ	A		9 pcs.	Pet tester Dwg. No. 28100560-T2, 3 & 4	
	2.0 Record V12 voltage					
	3.0 Record V3 voltage					
	4.0 Record input current					
	5.0 Overall efficiency - 30% min.					
	6.0 Voltage step up V12 and V3 - 107 ± 27 and 173 ± 43. Voltage step up ratio shall not decrease more than 2.0% or increase more than 4.5% from the initial measurement.	A		9 pcs.	Pet tester	
	7.0 Induced voltage (@ 3.75 volts peak)	A		9 pcs.	Pet tester	
	8.0 Primary capacitance - 14 ± 1.4 nf.	A		9 pcs.	Capacitance	
	9.0 Primary dissipation - 1.5% max.	A		9 pcs.	Bridge	
	10.0 Secondary capacitance (2) - 10 pf max.	A		9 pcs.		
	11.0 Secondary dissipation (2) - 1.5% max.	A		9 pcs.		
B	Post life - visual					
	1.0 Samples shall be examined for evidence of mechanical damage.	A		9 pcs.	Visual 7X	
C	Disposition					
	1.0 Record inspection results on QDR#1 and submit data to quality engineering for calculations. File data in lot folder. If the sample is rejected initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/30/78	Ripley	RS				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
		1	SD

WRITER	DATE	PART NUMBER	REV	MOD
R.Ripley	1/29/77	28100560	-	

INSPECTION PROCEDURE

HONEYWELL INC.

HI-10 REV.3 6/70

DIST.

INSP. DEPT.	CERTIFICATION REQ.	OP NUMBER	PART NAME	PART NUMBER	REV	MOD
6012	YES ☐ NO ☐	180 - S	Group "B" Subgroup 4 18MM - Solderability & Resistance to Solder Heat	28100560		

ITEM NO.	CHARACTERISTIC	CD		AQL	EQUIP	REF
A	Solderability					
	1.0 The terminals shall be properly prepared and dipped in a solder pot at 240 $\pm$ 5°C for 5 $\pm$ seconds. The terminals shall be immersed to within 3/64" from the nearest insulating material.	A		5 pcs	Solder pot temp controller soldering holder visual-7X	
	2.0 The terminals shall then be examined for proper tinning.					
B	Resistance to solder heat					
	1.0 The case shall be examined for damage from the above test.	A		5 pcs	Visual-7X	
	2.0 The terminals shall be tested at 1/2 lb. for terminal strength.	A		5 pcs.	Force gage Visual 7-X	
	3.0 The units shall then be opened very carefully and examined internally for loose or broken leads and other internal damage, broken ceramic etc.	A		5 pcs	Visual 10X	
C	Disposition					
	1.0 Record inspection results on QDR#1 and on appropriate data sheet. File data sheet in lot folder. If samples are rejected initiate MAR.					

ISSUE	DATE	APPROVAL	APPROVAL	ISSUE	DATE	APPROVAL	APPROVAL
2	1/30/78	Ripley	GEE				

DEVICE NUMBER	SPECIFICATION	DATA REC. NO.	SAMPLING PLAN NO.
PET		1	sp

WRITER	DATE	PART NUMBER	REV	MOD
R Ripley	1/29/77	28100560		

SECTION VI

ENGINEERING SAMPLE BUILDS

This section discusses the results obtained in building engineering samples. Two 25mm and three 18mm sets of samples were built for this effort.

A. FIRST ENGINEERING SAMPLES

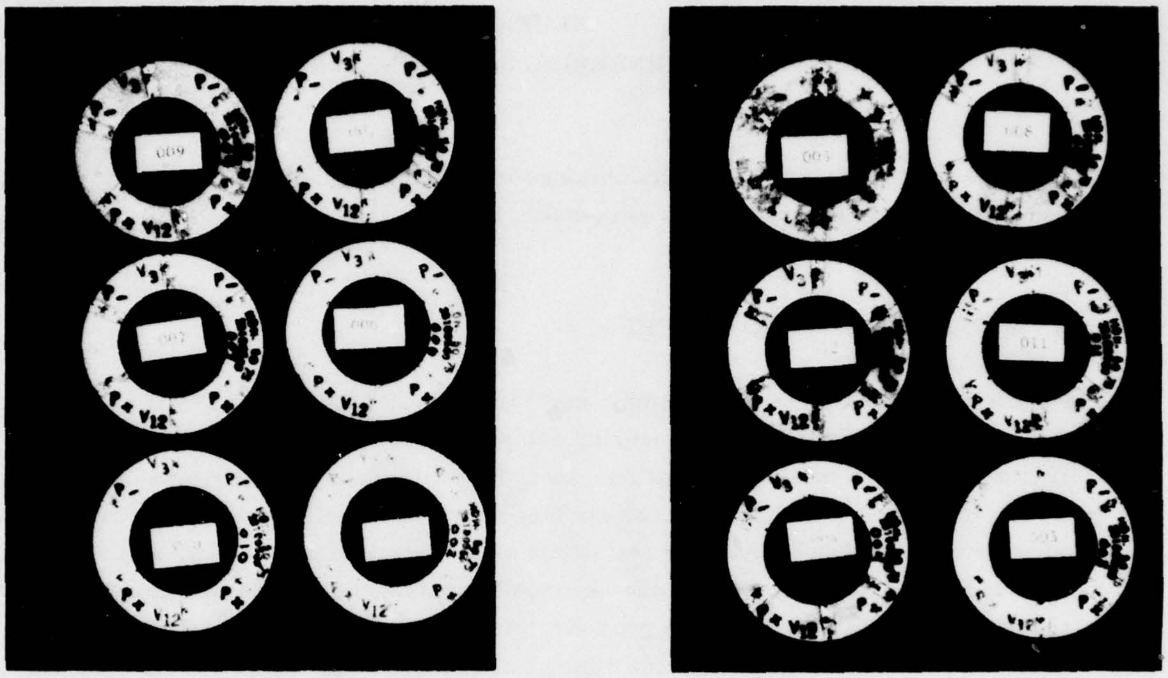
Figure 6-1(a) shows the twelve 18mm and Figure 6-1(b) the twelve 25mm packaged PETs that were built for the first engineering samples on this program. In the building of the 18mm samples, a major problem was encountered in the case design (as discussed previously). Figure 6-2 shows the voltage step-up ratio and efficiency of the half packaged units (one element) where 75 percent of the units (terminal on top side) met the voltage step-up ratio. Measurement on the second elements were unreliable because of the warpage and the inability to establish good electrical controls to the element at this stage of assembly. The final closure of the 18mm cases was hampered still further by the case warpage and the weak inside wall design. In many instances, direct pressure of the case on the ceramic elements caused low output voltage or, in a few instances, cracked an element. The approach of welding the shorting pins to the base and top shorting bars also proved to be an unreliable interconnection method.

Assembly of the 25mm elements was more satisfactory in that the cases were more substantial. A slight warpage (0.020 inch at the end of the 2.2-inch outside diameter of the half toroid) caused some interference of the case with the two ceramic elements. This was not a problem except where the shorting pin broke through the case insulation. The welding of the shorting pins to the top shorting bar was not carried out as planned because of this problem. Instead, soldering was used for these connections. Figure 6-3 gives individual half packages and completed assembly electrical data obtained.

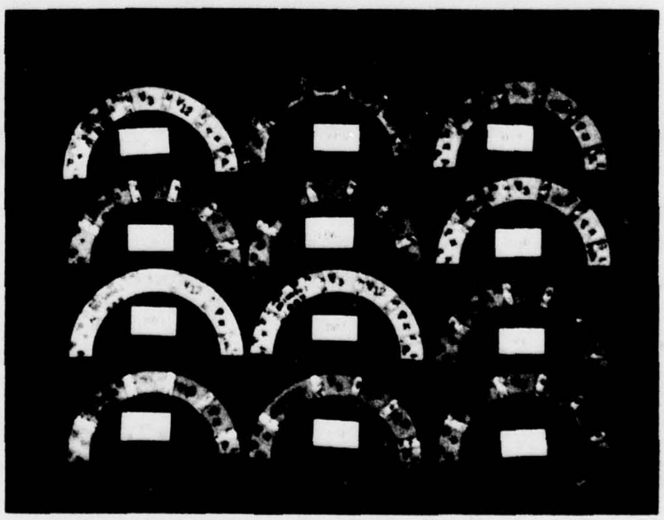
The results of the 18 and 25mm first engineering sample build are discussed for each specificate requirement below.

1. Item Definition

Figure 6-1 shows the twelve 18mm and twelve 25mm packaged PETs submitted for first engineering testing.



(a) 18mm PET Packages



(b) 25mm PET Packages

Figure 6-1. First Engineering Samples

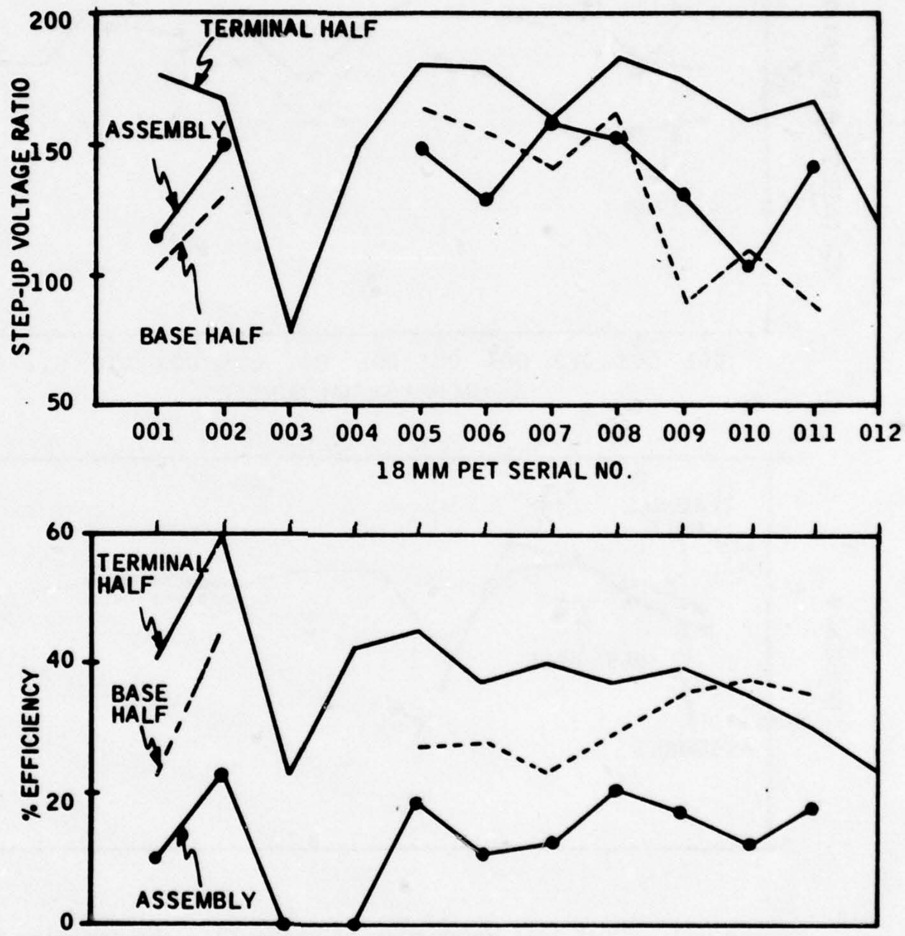


Figure 6-2. Electrical Properties of 18mm First Engineering Samples

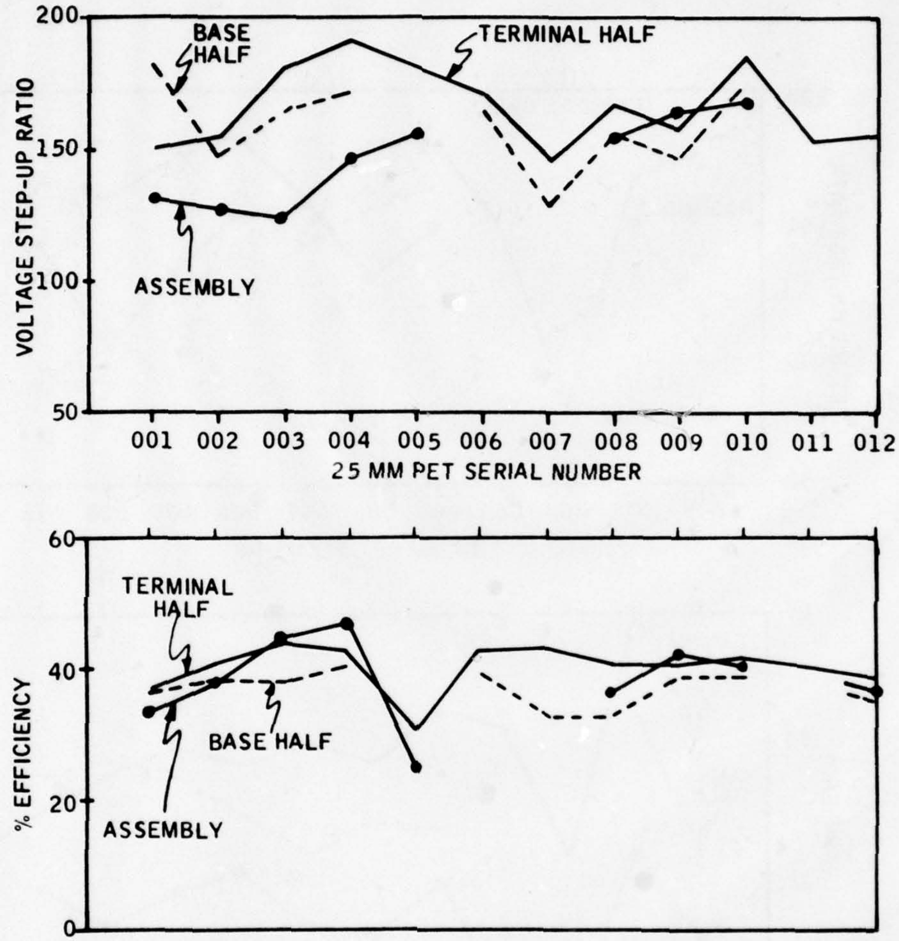


Figure 6-3. Electrical Properties of 25mm First Engineering Samples

2. Physical Characteristics

The weight of the completed 18mm and 25mm packages were 4.2 and 5.1 grams, respectively. The 18mm PETs were well within the 5-gram maximum allowed; however, the 25mm PETs are 0.1 to 0.2 gram heavy. Three units of each type of PET were dismantled and are shown in Figure 6-4. The 18mm samples 001 and 006 and 25mm sample 002 are mechanical shock samples. The weak inner wall of the 18mm samples failed to support the elements and cracked both ceramic elements in the 001 package. The warped base case in 004 also cracked the ceramic element in this half of the assembly. The 25mm sample case gave very adequate support, and no cracking of 25mm elements was encountered during shock and vibration. However, note in Figure 6-4 that the ceramic elements are close to the outside wall and shorting pin. This was caused by warpage of the package during injection molding.

3. Resistance to Soldering Heat

Figure 6-5 shows the 25mm PET units subjected to the solder reheat test. Serial No. 005 was dipped too far into the molten solder/flux and the package was damaged, but, when a 1/32-inch insulated pad was placed between the package and molten solder layer, only then was realistic terminal wetting obtained, and the packages passed this test requirement.

4. Solderability

The gold plated terminals, shorting straps and pins passed the solderability test.

5. Terminal Strength

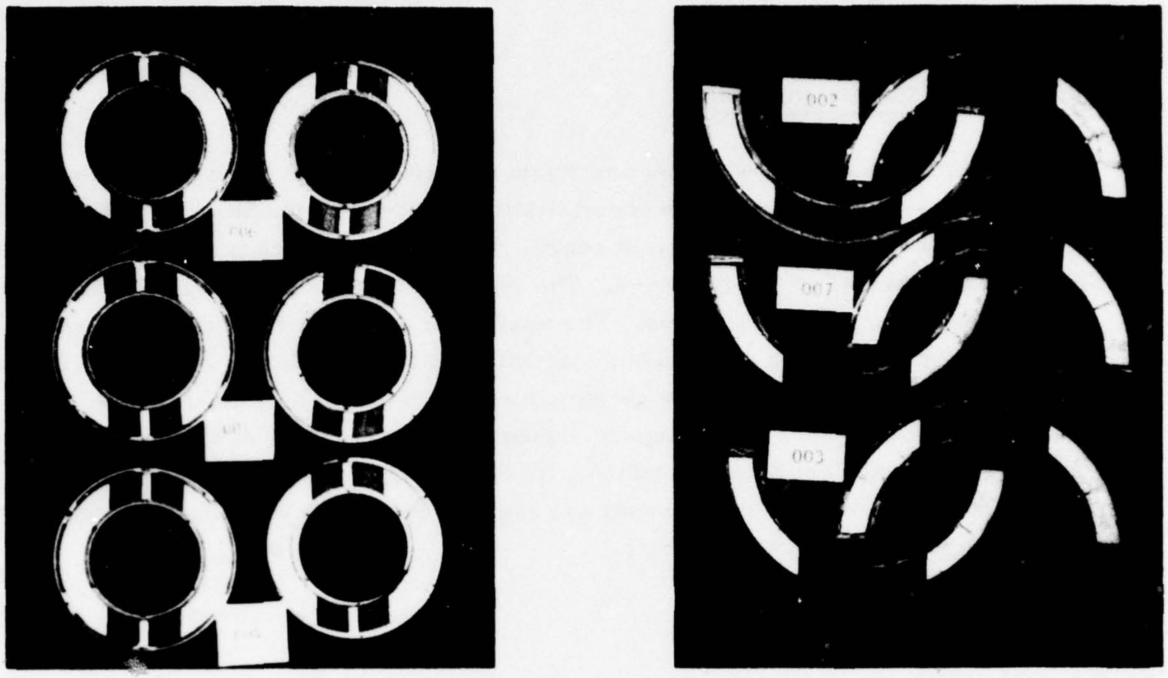
All units passed the terminal strength test. The staked terminals have a typical failure strength of 5 pounds or about ten times the half-pound requirement.

6. Induced Voltage

All units which operate satisfactorily at their 5-volt peak-to-peak input voltage can withstand the 7.5-volt peak-to-peak induced voltage test. However, the intermittent shorting problem encountered with the 25mm elements did cause one sample (009) to fail at 140 percent.

7. Electrical Properties

Tables 6-1 through 6-4 give the results of the electrical properties at or after various conditions for the 18 and 25mm PETs. The resonant frequency of these units was about



(a) 18mm PETs (b) 25mm PETs

Figure 6-4. Disassembled 18mm and 25mm Packages

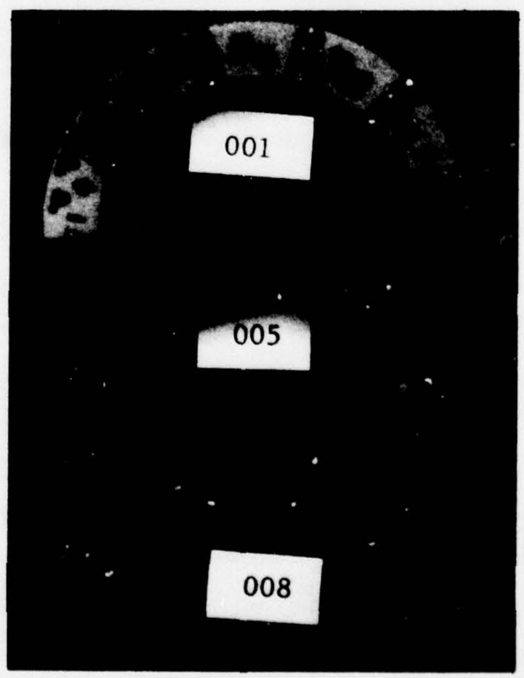


Figure 6-5. Resistance to Soldering Heat of 25mm PETs

Table 6-1. Summary of 18mm First Engineering Sample Test and Evaluation Results

SCS-480 ppg No.	Specified Parameter	001	002	003	004	005	006	007	008	009	010	011	012
3.1	Item Definition (Geometry)	← 13mm →											
3.2	Material	← Doped $Pb(ZrTi)O_3$ →											
3.3	Physical Characteristics	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
3.4	Resistance to Soldering Heat					Failed*			OK			OK	
3.5	Solderability			OK									OK
3.6	Terminal Strength			OK	OK								OK
3.7	Induced Voltage								OK			OK	
3.8	Room Temp. 5V p-p												
3.8.1	Resonant Frequency (kHz)	31.76	32.50			32.76	32.06	31.89	32.00	31.95	32.2	32.45	
3.8.2	Efficiency at Resonance (percent)	19	22			13	13	14	15	15	12	16	
3.8.3	Voltage Stepup Ratio at Resonance	102/94	144/135			104/100	104/96	156/150	155/151	131/132	111/98	148/132	
3.8.4	Input Capacitance (pf)/ Dissipation (percent)	26,230/0.85	24,650/0.64			26,930/0.57	36,230/0.74	37,120/0.84	34,130/0.80	35,140/0.78	33,290/0.78	33,690/0.65	
3.8.5	Secondary Capacitance (pf)/ Dissipation Factor (percent)	11.5/0.30	12.7/0.18			14.2/0.33	10.9/0.22	11.5/0.22	12.5/0.28	12.0/0.20	10.4/0.35	11.6/0.22	
3.9	High Temp. 52C ±2° 5 V p-p												
3.9.1	Resonance Frequency (kHz)	31.48	32.52			33.06	32.34	32.14	32.30	32.28	32.53	32.84	
3.9.2	Eff. at Resonance (percent)	14	20			15	13	15	15	15	12	15	
3.9.3	Voltage Stepup Ratio at Resonance	122/114	136/122			136/133	112/106	164/158	160/157	131/128	127/114	150/134	
3.10	Low Temp. -54 ±2°C 5 V p-p												
3.10.1	Resonance Frequency (kHz)	31.04	31.78			32.03	31.55	31.29	31.28	31.28	31.54	31.57	
3.10.2	Eff. at Resonance (percent)	12	17			11	11	13	14	13	10	13	
3.10.3	Voltage Stepup Ratio at Resonance	83/77	95/86			80/77	77/72	106/100	108/105	102/101	83/73	110/98	
3.11	Thermal Shock	OK	OK			OK	OK	OK	OK	OK	OK	OK	
3.12	High-Temp. Storage					OK		OK	OK	OK	OK	OK	
3.13	Low-Temp. Storage					OK		OK	OK	OK	OK	OK	
3.14	Humidity					OK			OK			OK	
3.15	Mechanical Shock	Failed	Failed				Failed						
3.16	Mechanical Vibration	OK	OK				OK						
3.17	Reduced Barometric Press.					OK			OK			OK	

*Dipped too far in solder

Table 6-2. 18mm First Engineering Sample Test Data

Test	S/N	Resonant Frequency (kHz)	Percent Efficiency	V_{12} Stepup Ratio	V_3 Stepup Ratio	Input Capacitance (pf)	Input Percent Dissipation	V_{12} Output Capacitance (pf)	V_{12} Output Percent Dissipation	V_3 Output Capacitance (pf)	V_3 Output Percent Dissipation
Room Temperature	001	31781	0.147	114	115						
	002	32801	0.238	149	152						
	005	32115	0.191	148	151						
	006	32370	0.156	130	127						
	007	32384	0.163	159	160						
	008	32926	0.207	155	151						
	009	32483	0.172	138	144						
	010	32550	0.126	104	94						
	011	32628	0.132		144						
Post-Temp. Shock	001	31760	0.187	102	94	26230	0.85	11.41	0.30	11.64	0.30
	002	32500	0.224	144	135	24640	0.64	12.67	0.18	12.68	0.18
	005	32755	0.127	104	100	26930	0.57	14.47	0.37	13.84	0.30
	006	32060	0.127	104	96	36230	0.74	10.97	0.24	10.88	0.20
	007	31891	0.144	156	150	37120	0.81	11.22	0.20	11.87	0.25
	008	32000	0.146	155	151	34130	0.80	12.40	0.25	12.51	0.31
	009	31953	0.154	131	132	35140	0.69	12.29	0.24	11.64	0.20
	010	32214	0.116	111	98	33290	0.78	10.68	0.40	11.07	0.30
	011	32450	0.164	148	132	33690	2.65	11.67	0.24	11.59	0.20
High-Temp Operation	001	31475	0.138	122	114						
	002	32518	0.195	136	122						
	005	33059	0.148	136	133						
	006	32340	0.125	112	106						
	007	32135	0.147	164	158						
	008	32300	0.145	160	157						
	009	32281	0.147	131	128						
	010	32531	0.121	127	114						
	011	32844	0.153	150	134						
Low-Temp Operation	001	31035	0.120	83	77						
	002	31782	0.169	95	86						
	005	32026	0.108	80	77						
	006	31547	0.110	77	72						
	007	31293	0.132	106	100						
	008	31383	0.135	108	105						
	009	31275	0.134	102	101						
	010	31544	0.095	82	73						
	011	31572	0.132	110	98						
High-Temp Storage	005	32115	0.150	136	133						
	007	32301	0.157	169	166						
	008	32373	0.146	160	158						
	009	32509	0.127	96	128						
	010	32543	0.116	122	109						
	011	32915	0.151	166	151						
Low-Temp Storage	005	32081	0.110	79	77						
	007	31283	0.135	106	102						
	008	31417	0.132	106	104						
	009	31481	0.108	77	98						
	010	31650	0.094	80	71						
	011	31671	0.131	104	93						
Humidity	005										
	008	32636	0.109	132	111						
	011	32420	0.122	118	110						
Resistance to Solder Heat and Barometric Pressure	005	No test - Unit dipped too deep									
	008	31863	0.127	81	82						
	011	31826	0.106	104	96						

Table 6-3. Summary of 25mm First Engineering Sample Test and Evaluation Results

SCS-480 ppg No.	Specified Parameter	001	002	003	004	005	006	007	008	009	010	011	012
3.1	Item Definition (Geometry)												
3.2	Material	← Doped $Pb(Zr\,Ti)O_3$ →											
3.3	Physical Characteristics	OK								OK	OK	OK	OK
3.4	Resistance to Soldering Heat	OK				Short/OK			OK				
3.5	Solderability	OK				OK			OK				
3.6	Terminal Strength						OK					OK	
3.7	Induced Voltage								OK	ARC 140%			OK
3.8	Room Temp. 5 V p-p												
3.8.1	Resonant Frequency (kHz)	30.60	30.60	30.11	30.25	30.11		29.74	30.11	30.15	30.17	Broken during assembly	30.09
3.8.2	Efficiency at Resonance (percent)	34	38	45	48	25		20	37	42	41		37
3.8.3	Voltage Step-up Ratio at Resonance	146/116	129/128	96/152	134/158	144/168		23/96	146/166	166/162	190/148		142/148
3.8.4	Input Capacitance (pf) Dissipation (percent)	44.060/0.88	43.210/0.99	31.940/0.83	32.510/0.83		42.800/0.80	42.670/1.01	42.170	45.400/0.80	44.170/0.73		46,080/1.3
3.8.5	Secondary Capacitance (pf) Dissipation Factor (percent)	9.5/0.58	9.1/0.35	9.9/0.55	9.9/0.54	11.9/0.58	8.8/0.80	10.1/0.65	9.2/0.28	12.0/0.59	10.4/0.18		11.5/0.62
3.9	High Temp. 52°C ± 2 C 5 V p-p												
3.9.1	Resonance Frequency (kHz)	30.11				31.21			30.24				
3.9.2	Eff. at Resonance (percent)	39							35				
3.9.3	Voltage Step-up Ratio at Resonance	149/101							129/155				
3.10	Low Temp. -54± 2 C 5 Vp-p												
3.10.1	Resonance Frequency (kHz)	29.31											
3.10.2	Eff. at Resonance (percent)	24											
3.10.3	Voltage Step-up Ratio at Resonance	77/84											
3.11	Thermal Shock	OK	OK	Short	OK	Short/OK			OK	OK	OK		OK
3.12	High-Temp. Storage	OK				Short/OK			OK				
3.13	Low-Temp. Storage	OK				Short/OK			OK				
3.14	Humidity	OK				Short/OK			OK				
3.15	Mechanical Shock		OK							OK			OK
3.16	Mechanical Vibration		OK							OK			OK
3.17	Reduced Barometric Press.	OK				Short/OK				OK			

Table 6-4. 25mm First Engineering Sample Test Data

Test	S/N	Resonant Frequency KHz	Percent Efficiency	V_{12} Stepup Ratio	V_3 Stepup Ratio	Input Capacitance (pf)	Input Percent Dissipation	V_{12} Output Capacitance (pf)	V_{12} Output Percent Dissipation	V_3 Output Capacitance (pf)	V_3 Output Percent Dissipation
Room Temperature	001	30539	0.352	143.2	146.8	44,210	0.98	9.38	0.1	10.10	0.20
	002	30462	0.383	136.8	137.2	45,300	1.07	8.74	0.1	9.80	0.2
	005	30087	0.240	149.8	164.8	Shorted	---	11.32	0.3	12.06	0.3
	008	30108	0.365	140.8	165.2	Shorted	---	8.88	0.08	9.32	0.28
	009	30123	0.430	169.2	167.2	45,320	0.86	11.84	0.3	11.64	0.2
	010	30168	0.392	181.6	143.6	44,160	0.8	10.17	0.17	10.21	0.2
	012	30077	0.380	147.6	155.2	11,131	1.58	9.09	0.20	2.70	---
Post-Temp Shock	001	29866	0.143	105.6	49.6						
	002	30022	0.365	122.0	124.0						
	004	30257	0.428	101.6	124.0						
	005	30132	---	---	119.2						
	008	29570	0.220	126.0	130.8						
	009	29444	0.171	119.6	117.0						
	010	29818	0.344	130.4	108.4						
	012	29390	0.157	105.2	116.4						
Post-Vibration	002	29847	0.080	80	65						
	009	30014	0.411	156	157						
	012	30169	0.410	103	111						
Post-Shock	002	30650	0.227	43	42						
	009	30072	0.392	143	141						
	012	29676	0.074	51	66						
High-Temp Storage	001	30767	0.388	102	149						
	005	31208	---	---	121						
	008	30239	0.350	129	155						
Low-Temp Storage	001	29805	0.236	84	77						
	005	29799	---	---	122						
	008		0.326								
		Shorted primary. OK after return to ambient.									
Post-Humidity	001	30352	0.338	100	144						
	005	32382	---	---	38						
	008	29919	0.337	125	138						
Resistance to Solder Heat and Barometric Pressure	001	30119	0.235	114	51						
	005	29660	---	---	52						
	008	29661	0.339	113	142						

35,000 and 42,000 pf; input and output dissipation was about 0.9 and 0.6 percent; and secondary capacitance was about 9 to 12 pf, respectively.

The critical properties of voltage step-up ratio and efficiency were not met by the 18mm packaged PET units largely because of the package design problem discussed. As shown in Figure 6-2, 75 percent of the half package units in the top or terminal case met the voltage step-up ratio, and the efficiency of these was 40 ± 4 percent as opposed to the desired 45 percent. Nine completed packages produced voltage step-up ratios of 90 to 156 with an average of 125. Efficiency was only 12 to 22 percent. At 52°C, the voltage step-up was about 9 percent better than at room temperature; however, no improvement in efficiency occurred. At -54°C, the average step-up ratio was 91. The low temperature efficiency did not drop off as rapidly as was anticipated.

Nine of the 25mm PET packages also had step-up ratios of 95 to 190 with an average of 147, which reflects the better package design. The efficiency was 25 to 48 percent with an average of 39 percent as opposed to the desired 50 percent.

At 52°C, the warpage problem discussed previously caused a problem with the three units evaluated. Unit 001 was about the same as at room termperature, while at -54°C the step-up ratio met the requirement and efficiency was 24 percent versus the 25 percent desired.

8. Thermal Shock

All nine 18mm and seven of the nine 25mm PET package units, which were initially operational, functioned after the specified thermal shock treatment. Two 25mm units, 003 and 005, contained short circuits of the primary electrodes. The thermal cycling apparently aggravated the warpage problem discussed earlier.

9. High-Termperature Storage

All 18 and 25mm units functioned after this test.

10. Low-Temperature Storage

All 18 and 25mm units functioned after this test.

11. Humidity

All 18 and 25mm units passed the required humidity test.

12. Mechanical Vibration

All 18 and 25mm PET units functioned properly after the required vibration test.

13. Mechanical Shock

All 25mm PET packaged units functioned properly after the required mechanical shock test. All 18mm failed this test because of the package problem discussed earlier.

14. Barometric Pressure

All 18 and 25 PET units evaluated passed the reduced barometric pressure test.

15. Life Test

Three 18mm PETs (007, 009, 010) and three 25mm PETs (008, 009, 010) were selected for life test evaluation and passed their 2000 hours of test without failure.

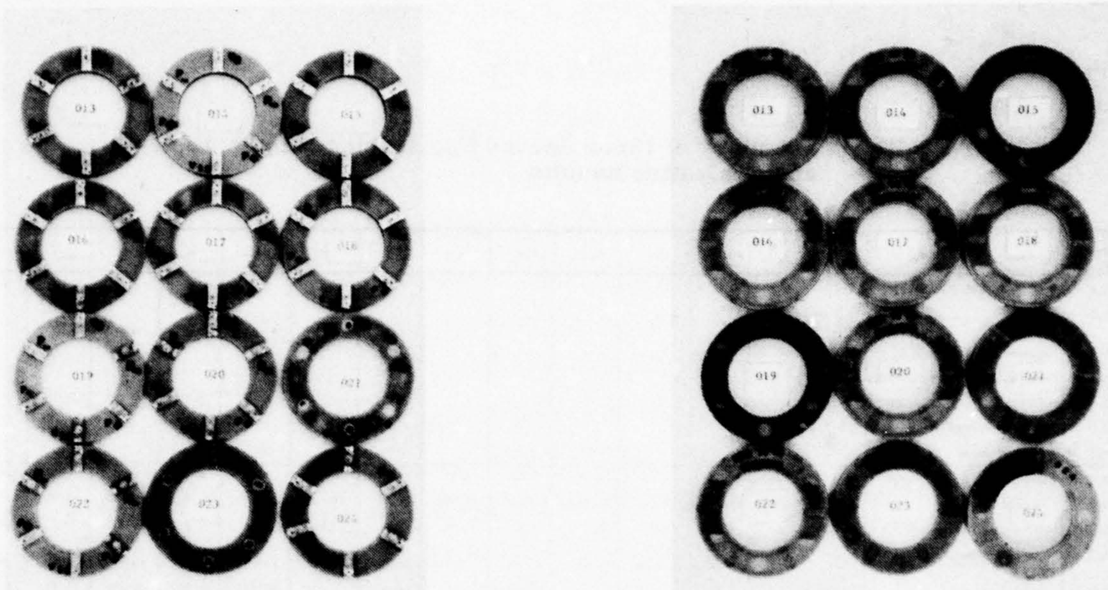
16. Sample Submitted

Nine 18mm packaged PETs were shipped on 2/5/75, nine 25mm PETs were shipped on 2/17/76 and six life test PETs (18 and 25mm) were shipped on 7/20/76 to complete our first engineering sample delivery except for life testing.

B. SECOND ENGINEERING SAMPLE BUILD

Twelve 18mm and 12 25mm PETs were built and submitted to inspection on June 11, 1976. The most significant changes incorporated in this build are: (1) elimination of the 18mm package problem, (2) elimination of the base side shorting bar and interconnections associated with the base side in both PET designs, (3) bonding of ceramic elements and (4) introduction of soldered gold ribbon leads.

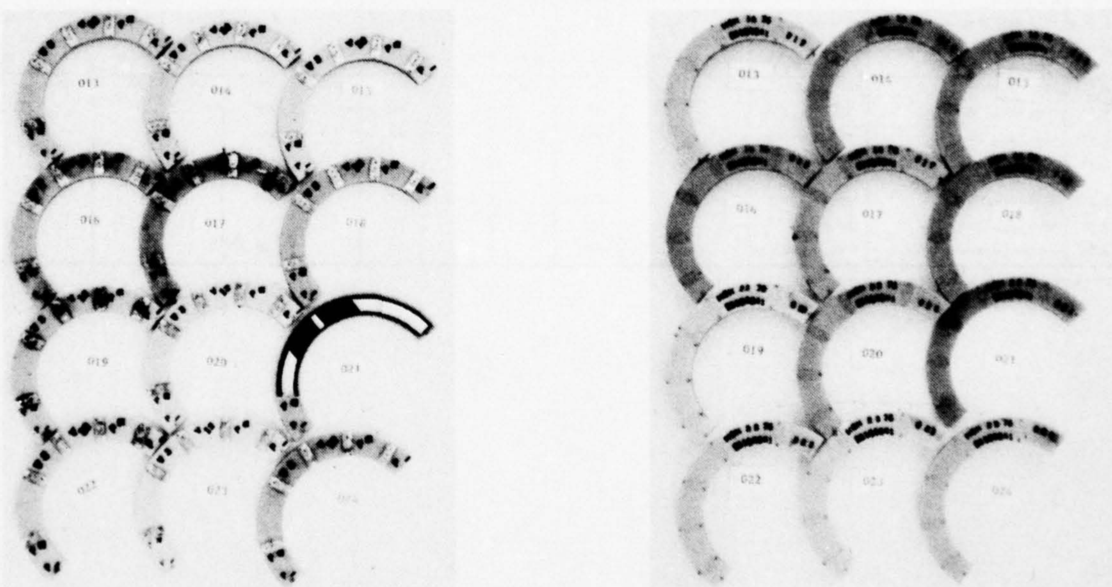
Figure 6-6 shows the twelve 18mm PETs, and Figure 6-7 the twelve 25mm PETs submitted as second engineering samples for test and evaluation. The test results are summarized in Tables 6-5 and 6-6 for the 18mm and 25mm PETs, respectively, while Tables 6-7 and 6-8 give the detail test data obtained. The results of the 18mm and 25mm second engineering sample build are discussed for each specification requirement on following pages.



a. Top Side

b. Base Side

Figure 6-6. 18mm PETs Submitted as Second Engineering Samples



a. Top Side

b. Base Side

Figure 6-7. 25mm PETs Submitted as Second Engineering Samples

Table 6-5. Summary of 18mm Second Engineering Sample Test and Evaluation Results

SCS-480 Page No.	Specified Parameter	18mm Requirement	013	014	015	016	017	018	019	020	021	022	023	024
3.1	Item Definition (Geometry)													
3.2	Material	Doped $Pb(ZrTi)O_3$												
3.3	Physical Characteristics	5 gms (max)												
3.4	Resistance to Soldering Heat	280°C/30 sec												
3.5	Solderability													
3.6	Terminal Strength	min 1/2 lb									OK		OK	
3.7	Induced Voltage	150%			OK			OK		OK				
3.8	Room Temp. Input Voltage	5 Volts (p-p)	4.77	4.63	4.37	4.73	4.11	4.47	4.59	3.47	4.36	4.02	4.78	4.31
3.8.1	Resonant Frequency	33.9 ± 0.2 kHz	29.724	32.791	31.863	29.669	31.766	31.875	38.917	32.478	31.553	31.863	39.335	30.992
3.8.2	Efficiency at Resonance	45% min	3.3	24.4	22.6	1.4	21.3	8.5	22.8	26.5	13.2	20.8		14.8
3.8.3	Voltage Step-up Ratio at V_{12}/V_3 Resonance	170 ± 17	23/23	100/98	127/128	19/21	156/147	67/75	142/0	240/243	98/100	157/162	0/0	105/112
3.8.4	Input Capacitance/ Dissipation	14,000 pf ± 4% 1.75% max	28.09/ 1.01			26.83/ 1.03		26.47/ 1.41		24.84/ 0.60	26.98/ 1.60	26.44/ 1.02	25.44/ 0.82	22.78/ 1.08
3.8.5	Secondary Capacitance Dissipation Factor	7.6 pf ± 4% 4.6% max	10.8/ 2.2	8.3/ 0.8	14.0/ 1.0	12.3/ 1.2	13.4/ 1.0	12.2/ 0.9	10.9/ 2.2	11.3/ 0.6				
3.9	High Temp. 52°C ± 2°C Input Voltage	5 Volts (p-p)	4.67	4.59	4.31	4.74	4.03	4.53	4.73	4.49	4.72	4.60		
3.9.1	Resonance Frequency	34.1 ± 0.2 kHz	38.669	32.988	31.837	38.686	31.970	32.020	38.682	33.025	38.684	30.704		
3.9.2	Efficiency at Resonance	50% min	0.3	24.6	21.6		21.7	10.7		32.8		24.7		
3.9.3	Voltage Step-up Ratio at V_{12}/V_3 Resonance	170 ± 17	13/4	107/103	132/132	10/16	167/155	68/81		139/135		102/106		
3.10	Low Temp. - 54 ± 2°C Input Voltage	5 Volts (p-p)	4.69	4.81	4.55	4.74	4.47	4.55	4.84	4.28	4.33	4.80		4.73
3.10.1	Resonance Frequency	33.3 ± 0.2 kHz	28.567	32.654	31.672	38.705	31.085	30.932	38.733	31.576	30.648	31.771		30.566
3.10.2	Efficiency at Resonance	25% min		15.5	17.9		14.4	4.0		15.4	7.4	18.7		9.6
3.10.3	Voltage Step-up Ratio at V_{12}/V_3 Resonance	85 ± 8.5	10/22	56/54	93/98	14/10	96/88	43/47	83/0	114/114	62/50	63/62		52/54
3.11	Thermal Shock	No Damage	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
3.12	High Temp. Storage	71°C 2 hrs min			OK			OK		OK				
3.13	Low Temp. Storage	-65°C 2 hr min			OK			OK		OK				
3.14	Humidity	95% RH at 52°C 6 hrs min			OK			OK		OK				
3.15	Mechanical Shock	per 4.5.13			*Failed			OK		OK				
3.16	Mechanical Vibration	per 4.5.12			OK			OK		OK				
3.17	Reduced Barometric Press.	3.44 in. for 1 hr			OK			OK		OK				

* PET unit crushed by mounting fixture.

Table 6-6. Summary of 25mm Second Engineering Sample Test and Evaluation Results

SCS-480 Page No.	Specified Parameter	18mm Requirement	013	014	015	016	017	018	019	020	021	022	023	024
3.1	Item Definition (Geometry)													
3.2	Material	Doped $Pb(ZrTi)O_3$												
3.3	Physical Characteristics	5 gms (max)												
3.4	Resistance to Soldering Heat	280°C/30 sec					OK		OK			OK		
3.5	Solderability						OK		OK			OK		
3.6	Terminal Strength	min 1/2 lb									OK			OK
3.7	Induced Voltage	150%						OK		OK			OK	
3.8	Room Temp. Input Voltage	5 Volts (p-p)	4.50	4.49	4.46	4.46	4.58	4.58	4.68	4.58	4.67	4.63	4.54	4.65
3.8.1	Resonant Frequency	33.9 ± 0.2 kHz	30.475	30.058	30.541	30.275	29.611	30.534	30.822	30.644	30.383	29.995	30.157	30.350
3.8.2	Efficiency at Resonance	45% min	56.0	50.8	58.4	57.7	30.8	44.4	45.9	45.3	34.2	12.5	22.9	36.5
3.8.3	Voltage Step-up Ratio at V_{12}/V_3 Resonance	170 ± 17	177/176	170/170	186/191	184/189	114/124	148/136	129/123	145/144	110/109	72/68	112/102	111/124
3.8.4	Input Capacitance/ Dissipation	14,000 pf ± 4% 1.75% max	31.22/ 0.90	33.83/ 0.67	30.63/ 0.89	32.04/ 0.80	32.34/ 1.00	32.09/ 0.77	21.64/ 0.62	34.62/ 0.47	22.77/ 0.63	32.39/ 0.61	30.55/ 0.69	30.86/ 0.70
3.8.5	Secondary Capacitance Dissipation Factor	7.6 pf ± 4% 4.6% max	14.2/ 0.82	6.6/ 0.84	10.4/ 0.66	18.9/ 0.90	14.4/ 0.87	6.6/ 0.88	13.7/ 0.98	13.7/ 0.78	13.7/ 1.19	16.5/ 0.84	10.1/ 0.78	10.5/ 0.46
3.9	High Temp. 52°C ± 2° Input Voltage	5 Volts (p-p)	4.42	4.49	4.40	4.39	4.52	4.45	4.61	4.44	4.61	4.69	4.54	4.44
3.9.1	Resonance Frequency	34.1 ± 0.2 kHz	30.709	30.282	30.796	30.503	29.519	30.731	30.801	30.804	30.439	30.074	30.289	30.321
3.9.2	Efficiency at Resonance	50% min	58.9	51.7	57.7	57.1	20.7	48.0	30.9	48.1	36.9	9.3	24.7	33.1
3.9.3	Voltage Step-up Ratio at V_{12}/V_3 Resonance	170 ± 17	197/198	171/173	197/200	197/200	102/108	179/165	117/113	175/174	125/125	56/54	115/108	152/135
3.10	Low Temp. -54 ± 2°C Input Voltage	5 Volts (p-p)	4.58	4.54	4.55	4.54	4.60	4.57	4.74	4.55	4.73	4.68	4.60	4.59
3.10.1	Resonance Frequency	33.3 ± 0.2 kHz	29.418	29.128	29.359	29.201	28.845	29.464	29.814	29.621	29.311	28.295	29.473	29.324
3.10.2	Efficiency at Resonance	25% min	21.7	20.5	11.3	18.7	25.3	10.5	23.9	9.4	23.8	9.0	17.2	16.4
3.10.3	Voltage Step-up Ratio at V_{12}/V_3 Resonance	85 ± 8.5	100/99	105/100	77/72	100/96	103/107	68/73	86/77	69/67	82/82	57/54	113/82	92/78
3.11	Thermal Shock	No Damage	OK	OK	OK	OK	OK	OK	*OK	OK	OK	OK	OK	OK
3.12	High Temp. Storage	71°C - 2 hrs min						OK		OK			OK	
3.13	Low Temp. Storage	-65°C 2 hr min						OK		OK			OK	
3.14	Humidity	95% RH at 52°C 6 hrs min						OK		OK			OK	
3.15	Mechanical Shock	per 4.5.13						OK		OK			**Failed	
3.16	Mechanical Vibration	per 4.5.12						OK		***Failed			OK	
3.17	Reduced Barometric Press.	3.44 in. for 1 hr						OK		OK			OK	

* V_3 open, V_{12} OK

** PET crushed by mounting fixture

*** V_{12} open, V_3 OK

Table 6-7. 18mm Piezoelectric Transformer Summary of Test Results — Second Engineering Sample

	S/N	Resonant Frequency (kHz)	Percent Efficiency*	Step-up* Ratio $_{12}$	Step-up* Ratio $_{3}$	Input Capacitance (nf)	Input Dissipation (%)	Output** Capacitance $_{12}$ (pf)	Output Dissipation $_{12}$ (%)	Output** Capacitance $_{3}$ (pf)	Output Dissipation $_{3}$ (%)
Room Temperature Prior to Environments	013	29.730	4.3	47.2	26.8						
	014	32.736	17.1	145.6	144.8						
	015	32.001	20.7	143.6	148.4						
	016	31.600	4.5	32.0	25.6						
	017	32.183	20.0	138.4	134.8						
	018	32.202	9.3	64.8	53.6						
	019	32.289	18.4	151.2	162.8						
	020	32.579	19.0	180.4	180.0						
	021	30.961	-	29.6	16.0						
	022	32.174	19.0	141.6	148.0						
	023	33.888	-	12.8	20.4						
	024	31.410	10.3	72.8	82.8						
Post-Temp. Shock (Ambient)	013	29.724	-	21.6	31.2	28.09	1.01	18.56	2.12	19.10	2.30
	014	32.791	22.6	92.4	90.4	-	-	16.93	0.79	15.57	0.83
	015	31.863	19.8	110.8	112.0	-	-	21.67	0.90	22.31	1.09
	016	29.669	-	17.6	20.0	26.83	1.03	20.44	1.14	20.13	1.17
	017	31.766	17.5	128.4	120.8	-	-	20.33	0.89	22.55	1.07
	018	31.875	9.9	59.6	66.8	26.47	1.41	20.60	1.04	19.83	0.83
	019	38.917	-	130.4	0	-	-	16.76	2.08	21.07	2.25
	020	32.478	18.4	166.8	168.8	24.84	0.60	18.81	0.35	19.82	0.82
	021	31.553	11.5	85.2	87.2	26.98	1.60	20.15	0.97	20.15	0.67
	022	31.863	16.7	126.0	130.4	26.44	1.02	20.05	0.89	18.50	0.70
	023	39.335	-	8.8	4.0	25.44	0.82	19.89	-	-	-
	024	30.992	12.7	90.4	96.4	27.78	1.08	15.24	0.86	14.45	0.8
Post-Temp. Shock (High Temp.)	013	38.669	-	12.0	4.0						
	014	32.988	22.6	98.0	94.8						
	015	31.837	18.6	113.6	113.6						
	016	38.686	-	9.2	15.2						
	017	31.970	17.5	134.8	125.2						
	018	32.020	9.7	61.2	73.2						
	019	38.682	-	9.2	0.4						
	020	33.025	29.4	125.2	120.8						
	021	38.684	-	-	-						
	022	30.704	22.7	94.0	97.6						
	023	-	-	-	-						
	024	-	-	-	-						
Post-Temp. Shock (Low Temp.)	013	28.567	-	9.2	20.4						
	014	32.654	14.9	54.4	52.0						
	015	31.672	16.6	84.4	88.8						
	016	38.705	-	13.2	9.6						
	017	31.085	12.9	86.0	78.8						
	018	30.932	3.6	38.8	42.8						
	019	38.733	-	2.0	-						
	020	31.576	13.2	97.6	97.6						
	021	30.648	6.9	53.6	43.2						
	022	31.771	17.9	60.0	59.6						
	023	-	-	-	-						
	024	30.566	-	48.8	50.8						

* Values have not been corrected for lower input voltage levels.
** Values have not been corrected for about 8 pf stray capacitance.

Table 6-7. 18mm Piezoelectric Transformer Summary of Test Results — Second Engineering Sample (Concluded)

	S/N	Resonant Frequency (kHz)	Percent Efficiency*	Step-up Ratio $_{12}$*	Step-up Ratio $_3$*	Input Capacitance (nf)	Input Dissipation (%)	Output Capacitance $_{12}$** (pf)	Output Dissipation $_{12}$ (%)	Output Capacitance $_3$** (pf)	Output Dissipation $_3$ (%)
Induced Voltage	015	OK	OK	OK	OK						
	018	OK	OK	OK	OK						
	020	OK	OK	OK	OK						
Baro-metric Pressure	015	32.440	27.0	90.8	86.8						
	018	32.340	8.8	48.8	52.0						
	020	32.529	18.4	171.6	175.2						
Post-Humidity	015	32.247	25.1	82.0	82.8						
	018	32.124	9.1	54.4	45.2						
	020	32.395	16.3	148.0	146.8						
Post-Temp. Storage (High)	015	32.581	9.8	93.2	94.8						
	018	32.195	17.6	72.4	61.6						
	020	32.631	27.6	170.4	170.0						
Post-Temp. Storage (Low)	015	31.893	4.1	56.8	55.2						
	018	31.327	12.0	47.2	36.0						
	020	31.996	20.4	96.0	92.8						
Post-Vibration	015	32.457	26.6	88.8	87.6						
	018	32.342	9.1	54.4	44.0						
	020	32.617	18.5	175.2	172.4						
Post-Shock	015	30.141	-	12.4	9.6						
	018	31.274	5.8	56.0	40.4						
	020	32.653	18.2	166.0	162.8						
Terminal Strength	021	OK	OK	OK	OK						
	023	OK	OK	OK	OK						
Solder-ability	013	OK	OK	OK	OK						
	016	OK	OK	OK	OK						
	019	OK	OK	OK	OK						
Life Tests	014	33.172	25.6	105.2	102.8	750 Hours					
	017	32.189	18.9	140.4	127.6	750 Hours					
	022	32.190	19.4	145.6	150.4	750 Hours					

* Values have not been corrected for lower input voltage levels.
** Values have not been corrected for about 8 pf stray capacitance.

Table 6-8. 25mm Piezoelectric Transformer Summary of Test Results — Second Engineering Sample

	S/N	Resonant Frequency (kHz)	Percent Efficiency *	Step-up Ratio 12 *	Step-up Ratio 3 *	Input Capacitance (nf)	Input Dissipation (%)	Output Capacitance 12 ** (pf)	Output Dissipation 12 (%)	Output Capacitance 3 ** (pf)	Output Dissipation 3 (%)
Room Temperature Prior to Environments	013	30.683	[illegible]7.6	193.6	196.4						
	014	30.303	52.3	177.6	180.0						
	015	30.769	55.5	181.2	186.0						
	016	30.533	53.9	184.4	189.2						
	017	29.696	20.7	102.4	93.6						
	018	30.635	44.2	161.2	148.0						
	019	30.815	42.2	122.4	125.6						
	020	30.755	47.2	168.8	166.8						
	021	30.507	45.5	131.6	129.2						
	022	30.159	23.3	103.6	102.8						
	023	30.130	26.2	116.0	120.8						
	024	30.476	35.0	103.6	114.4						
Post-Temp. Shock (Ambient)	013	30.475	50.4	159.6	158.4	31.22	0.90	22.68	0.76	21.76	0.88
	014	30.058	45.6	152.8	152.8	33.83	0.67	10.34	0.98	18.90	0.70
	015	30.541	52.1	166.4	170.4	30.63	0.89	18.80	0.60	1[illegible].03	0.71
	016	30.275	51.5	164.4	168.4	32.04	0.80	27.60	0.80	26.19	0.99
	017	29.611	28.2	104.8	113.6	52.34	1.00	23.00	0.80	21.72	0.94
	018	30.534	40.7	135.5	124.4	32.09	0.77	10.71	0.97	18.49	0.79
	019	30.822	43.0	120.8	115.2	21.64	0.62	21.57	0.89	21.76	1.06
	020	30.644	41.5	132.8	137.0	34.62	0.47	22.60	0.66	20.83	0.89
	021	30.383	31.9	103.2	102.0	22.77	0.63	21.32	1.28	22.01	1.09
	022	29.995	11.5	66.8	63.2	32.39	0.61	25.43	0.79	23.64	0.88
	023	30.157	20.8	101.6	92.8	30.55	0.69	18.70	0.70	17.42	0.86
	024	30.350	34.0	103.2	115.2	30.86	0.70	18.61	0.53	18 34	0.38
Post-Temp. Shock (High Temp. Operation)	013	30.709	52.1	174.0	174.8						
	014	30.282	46.4	153.2	155.2						
	015	30.796	50.8	173.2	176.0						
	016	30.503	50.3	173.2	176.4						
	017	29.519	18.7	92.0	98.0						
	018	30.731	42.7	159.6	147.2						
	019	30.801	28.5	108.0	104.0						
	020	30.804	42.7	155.2	154.8						
	021	30.439	34.0	114.8	115.6						
	022	30.074	8.7	52.8	50.4						
	023	30.289	22.5	104.4	98.4						
	024	30.321	29.4	135.2	120.0						
Post-Temp. Shock (Low Temp. Operation)	013	29.418	19.9	91.2	90.8						
	014	29.128	18.7	95.2	90.8						
	015	29.359	10.3	70.0	65.6						
	016	29.201	17.0	90.4	87.2						
	017	28.845	23.3	94.4	98.0						
	018	29.464	9.6	62.0	66.4						
	019	29.814	22.7	81.2	72.8						
	020	29.621	8.52	62.4	61.2						
	021	29.311	22.3	77.6	77.2						
	022	28.295	8.4	53.2	50.8						
	023	29.473	15.8	82.8	75.2						
	024	29.324	15.1	84.8	72.0						

* Values have not been corrected for lower input voltage levels.
** Values have not been corrected for about 8 pf of stray capacitance.

Table 6-8. 25mm Piezoelectric Transformer Summary of Test Results — Second Engineering Sample (Concluded)

Test	S/N	Resonant Frequency (kHz)	Percent Efficiency*	Step-up Ratio$_{12}$*	Step-up Ratio$_3$*	Input Capacitance (nf)	Input Dissipation (%)	Output Capacitance$_{12}$** (pf)	Output Dissipation$_{12}$ (%)	Output Capactiance$_3$** (pf)	Output Dissipation$_3$ (%)
Induced Voltage	018	OK	OK	OK							
	020	OK	OK	OK							
	023	OK	OK	OK							
Baro-metric Pressure	018	30.697	46.4	146.8	161.2						
	020	30.761	48.2	164.8	166.0						
	023	30.385	29.0	122.8	116.4						
Humidity	018	30.504	41.1	142.4	129.2						
	020	30.566	42.8	142.4	142.0						
	023	30.366	24.4	68.0	69.6						
Post-Temp. Storage (High)	018	30.916	13.8	81.2	72.4						
	020	30.575	9.9	77.6	72.8						
	023	30.457	21.1	58.4	59.2						
Post-Temp. Storage (Low)	018	29.415	15.4	70.8	61.2						
	020	29.890	20.2	95.2	92.0						
	023	29.996	6.0	63.2	14.8						
Vibration	018	30.830	33.6	120.0	105.6						
	020	31.576	35.1	18.4	213.2						
	023	30.449	24.5	107.6	107.2						
Post-Shock	018	30.917	49.3	103.6	91.6						
	020	31.034	15.9	10.8	110.0						
	023	29.702	5.6	31.2	23.6						
Solder-ability	17	OK	OK	OK	OK						
	19	OK	OK	OK	OK						
	22	OK	OK	OK	OK						
Resist to Solder Heat	17	Dipped too deep									
	19	30.657	32.0	100.8	100.4						
	22	No physical damage but unit was dropped on the floor prior to the test and it was no longer working at the time it was dipped into the solder.									
Terminal Strength	21	OK	OK	OK	OK						
	24	OK	OK	OK	OK						
Life Tests	13										
	15	In progress									
	16										

* Values have not been corrected for lower input voltage levels.
** Values have not been corrected for about 8 pf of stray capacitance.

1. Physical Characteristics: The weight of the revised 18mm and 25mm package PETs was 4.2 and 4.85 grams, respectively. The redesigned 18mm case performed quite satisfactorily and the warpage of the 25mm case was corrected by annealing. The wall thickness of the top and base 25mm cases was found to be oversize by 0.006 and 0.015 inch, which led to the assembled case being 0.010 inch oversize in outside thickness and undersize about 0.010 inch inside clearance. The injection mold die will be reworked to correct this problem. A package weight reduction of about 0.3 gram was obtained and thus the 25mm PETs will weigh about 4.5 grams.

2. Resistance to Soldering Heat: As with the first engineering samples, when only the terminals were in contact with the solder, the packaged units survived the soldering heat resistance tests. One 25mm unit (No. 017) was dipped too far into the flux/solder bath and the face of the top case was partially melted.

3. Solderability: All units passed the solderability tests.

4. Terminal Strength: The terminals on two 18mm (021 and 023) and one 25mm (021) units were pulled to destruction. Typical pull strengths were 10 to 12 pounds. After several pounds of loading, the terminals remain tight and secure to the package.

5. Induced Voltage: No failure to the induced voltage test occurred.

6. Thermal Shock: All twelve 25mm and seven of eight 18mm PET package units that were initially operational functioned after the specified thermal shock treatment. One 18mm unit (019), which functioned prior to thermal shock, contained only one output afterwards while another 18mm unit (021), which was unsatisfactory prior to thermal shock, produced outputs from both secondaries.

7. High Temperature Storage: All 18mm and 25mm PETs passed this test.

8. Low Temperature Storage: All 18mm and 25mm PETs passed this test.

9. Humidity: All 18mm and 25mm PETs passed the required humidity test.

10. Mechanical Vibration: All 18mm and 25mm PETs passed this test except one V_{12} output in a 25mm unit (020).

11. Mechanical Shock: One 18mm and one 25mm PET unit failed to operate after the mechanical shock test; however, all six units were partially crushed during the mounting of the PETs in the test fixture. Rubber mounting pads will be added to the test fixture to prevent future damage.

12. Barometric Pressure: All 18mm and 25mm PET units passed the reduced barometric pressure test.

13. Life Test: Three 18mm (014, 017, 022) and three 25mm (013, 015, 016) PET units were selected and placed on life test June 7, 1976. These units reached 750 hours of testing without failure. These parts were delivered to NV and EOL on July 20, 1976.

14. Electrical Performance: Eight of the 18mm PETs and 11 of the 25mm PETs produced significant output voltage.

C. 18MM PET

Three 18mm PETs were damaged during the final stages of closing the packages, while one unit was apparently damaged during bonding and insertion into the top case.

Seven of the eight operational 18mm PETs (S/N 014, 015, 017, 018, 020, 021 and 022) were of similar design, while S/N 024 contained the single primary single secondary type "M" electrode design discussed earlier. Only the standard electroded packages are discussed below.

The average resonant frequency of the 18mm units was 32.15 kHz with a range of 31.55 to 32.79 kHz, which is slightly higher than the first engineering samples. The input capacitance was 25.07 nf, which is lower than the 34.93 nf obtained with wide electrode first engineering samples. The secondary capacitance and dissipation of 12 pf and 0.9 percent were about the same as the previous set of PETs. The input dissipation of 1.0 percent was also about the same as previously.

The desired room temperature voltage step-up ratio was met by only two PETs, S/N 020 and 022, while S/N 017 contained one acceptable output and a second output only slightly below the minimum desired of 153. The high temperature performance was normally equal to or slightly better than the room temperature; for instance, both outputs of S/N 017 were satisfactory However, the output of S/N 020 and 022 decreased significantly. Poor contact of the PETs terminals to the test fixture probably explains the low output of S/N 015, 017 and 020. In fact, the drop in output at -54°C was not as great as had been anticipated.

The efficiency at resonance at all temperatures was less than desired. At room temperature and 52°C, the best units were only 24 to 26 percent as opposed to the desired 45 percent, while at -54°C, 15 to 18 percent efficiency was obtained instead of the desired 25 percent minimum. Thus, at least a part of low output and efficiency of the first engineering samples was not a case problem, but a design/testing problem.

The 25mm PETs had an average input capacitance of 32 nf as opposed to the 44 nf wider electrode, first engineering samples. Input dissipation was 0.8 percent, which was about the same as the first engineering samples. Resonant frequency of the second engineering samples averaged 30.5 kHz as opposed to 30.2 kHz for the previous samples.

The voltage step-up desired at room temperature and 52°C was met by six of the 25mm PETs, S/N 013, 014, 015, 016, 018, and 020. At -54°C, S/N 015 and 018 were slightly below the desired ratio. The efficiency at resonance at room temperature and 52°C was greater than 50 percent and three others were about 45 percent. At -54°C, five units had an efficiency between 20 and 26 percent. At -54° and +52°C temperatures, the resonant frequency was about 1.0 kHz lower and 0.2 kHz higher, respectively, than the PETs' room temperature value.

D. ADDITIONAL SECOND ENGINEERING SAMPLES

Based on the low efficiency and marginal voltage step-up ratio achieved in the twelve 18mm PETs built earlier, several modifications to the 18mm PET design were made. Three additional packaged units were built with the following changes: One element was eliminated because of the higher step-up voltages achieved. The electrical load on each secondary was altered to make it more compatible with an 18mm power supply. These conditions are a V_{12} loading of 2×10^6 ohms and 8 pf and a V_3 loading of 1×10^8 ohms and 3 pf.

Table 6-9 compares the data obtained for these three units (025, 026 and 027) against a double element unit (020) at several loading conditions. The thinner element unit (026) had 7 to 10 percent lower efficiency and also lower voltage step-up than the normal thickness unit (027). The well-aged unit (025) had the same efficiency but higher step-up voltage than the newer unit (027). The double unit (020) had a 10 percent lower efficiency than the single unit (025). The impact of different electrical loads on the PET is seen for unit (027). The power supply loading produced the maximum efficiency and voltage step-up.

It was concluded that a single element 18mm PET would drive the 18mm power supply and that the load requirements on the V_{12} and V_3 outputs should be altered to 2×10^6 ohm/8 pf and 1×10^8 ohm/3 pf, respectively.

Table 6-9. Additional 18mm Test Data

LOAD	$10^7\ \Omega$ and 10pf		$10^7\ \Omega$ and 8pf		V_{12} $2\text{x}10^6\ \Omega$ and 8pf; V_3 $1\text{x}10^8\ \Omega$ and 3pf		
	RT	-54°C	RT	-54°C	RT	-54°C	Remarks
Step-up V_{12}	196		213	102			Single Ceramic Element, 0.010-in. thick, well-aged part.
Step-up V_3	176		192	89			
F_R kHz	32.66		32.81	31.73			
Percent Eff.	26.5		35.1				
Step-Up V_{12}	121		135	88			Single Ceramic Element, 0.008-in. thick, 14-day-old part.
Step-Up V_3	128		140	89			
F_R kHz	31.73		31.93	31.21			
Percent Eff.	19.6		25.7				
Step-up V_{12}	160		176	101	110	75	Single Ceramic Element, 0.010-in. thick, well-aged part.
Step-up V_3	164		178	104	181	120	
F_R kHz	32.23		32.43	31.82	32.28	31.79	
Percent Eff.	28.1		35.1		41.7	18.4	
Step-up V_{12}			228		160	76	Double Ceramic Element. 0.010-in. thick, well-aged part
Step-up V_3			222		216	96	
F_R kHz			32.85		32.74		
Percent Eff.			24.7		40.8		

SECTION VII

CONFIRMATORY BUILD AND PILOT RUN

The confirmatory build and pilot run manufacturing trials are discussed in this section.

A. INITIAL CONFIRMATORY BUILD

Approval to start the manufacture of confirmatory 18mm and 25mm PET units was obtained 22 December 1976. The initial 18mm build of 35 parts was completed in January 1977. A summary of the test results is given in Table 7-1. The initial testing of these identified several process weaknesses which needed correction. Several of the packages did not pass the resistance to solder reheating test. The closure pins, soldered to the shorting bars on the terminal side of the package, became loose during the solder reheat test and the package partially popped open. In future packages, the closure pins were reversed so that the shoulder of the pin was on the terminal side and crimping of the pin on the reverse side was used to seal the package.

Detailed results on the first submittal 18mm PETs are presented in Table 7-2. After completion of the test sequence, only 12 of the 30 18mm units met all specifications. Nine other units met efficiency and V_{12} voltage step-up, but the V_3 step-up voltage was low - between 130 and 145. Nine units completely failed because (1) the resistance to solder heat test melted solder around the closure pins and the package popped open, which broke lead wires and ceramic or caused open circuits; (2) the packages were flexed too far when inserted or removed from the test fixtures; or (3) they were accidentally overheated during the solder reheat test.

Specific test parameters which presented a problem were the post humidity, solder heat and heat shock. All units failed the immediately after post humidity test because the PET packages are not sealed. After internal moisture was dried out of the PET, all units performed satisfactorily. Since they are encapsulated with other supply components, it was determined that the humidity test should not be imposed on these units. While no problem was encountered with the barometric pressure test, it was also determined that this test was more appropriate to the encapsulated PETs. Therefore, the barometric pressure test was also eliminated from the test sequence.

About half of the twenty-eight 18mm units which met critical requirements before thermal shock passed the thermal shock test, but the other half were low in voltage step-up until a later time. They then returned to normal operation. One unit, which was satisfactory prior to heat shock, did not recover because a leadwire to the V_{12} output was broken.

Table 7-1. Summary of Test Results on First and Second Submittals for Confirmatory Build

	18mm PET's				25mm PET's	
	First Submittal*		2nd Submittal**		1st Submittal*	
	Number Good/ Tested	Percent Good	Number Good/ Tested	Percent Good	Number Good/ Tested	Percent Good
Post-Thermal Shock	11/30	37	31/31	100	2/30[E]	7[E]
High Temp Storage/Operation	18/30	60	3/3***	100	6/30[E]	20[E]
Low Temp Storage/Operation	10/30	33	3/3***	100	11/30	37
					23/30[E]	77[E]
Capacitance (Primary)	29/30	97	13/13	100	2/18	11
Capacitance (Secondary)	30/30	100	13/13	100	8/18	44
Terminal Strength	30/30	100	13/13	100	18/18	100
Solder Heat	15/20	75	3/3***	100	21/21	100
Post-Solder Heat	11/20	55	3/3	100	2/21[E]	10[E]
Induced Voltage	20/20	100	13/13	100	14/20	70
Solderability	3/3	100	3/3	100	30/30	100
Post-Barometric Pressure	3/3	100	NR	NR	3/3	100
Post-Humidity	0/3	0	NR	NR	0/3	0
Induced Voltage	3/3	100	3/3	100	3/3	100
Visual External/Internal			3/3	100	3	
Life (during)	3/9	33	9/9	100	0/9	0
Post-Life	4/9	44	9/9	100	0/9	0
Mechanical Vibration	2/7	29	7/7	100	2/7[E]	29[E]
Mechanical Shock	3/7	43	7/7	100	1/7[E]	14[E]
Induced Voltage	7/7	100	7/7	100	3/3	100

* Initial specification

** Final specification

*** Group II Test

NR Not Required

E Based on voltage step-up only. Percent efficiency less than 50 percent at room temperature or less than 20 percent at low temperature.

Table 7-2. First Submittal - 18mm Confirmatory Samples
A. Group I Test

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance Input (nf)	Capacitance V_{12} (pf)	Capacitance V_3 (pf)	Dissipation (Percent) Input	Dissipation (Percent) V_{12}	Dissipation (Percent) V_3	Terminal Strength	Induced Voltage
Post Thermal Shock	33	31.668	40.2	97.45	150.71							OK	OK
	34	32.135	43.1	98.02	143.9*							OK	OK
	37	31.914	48.8	112.75	166.01							OK	OK
	54	31.913	37.2*	95.18	140.58							OK	OK
	56	31.676	37.5*	86.69*	125.21*							OK	OK
	59	32.070	41.7	99.72	141.64*							OK	OK
	63	31.873	35.6*	90.65	137.68*							OK	OK
	64	31.464	33.8*	82.15*	122.95*							OK	OK
	67	32.005	42.5	103.68	155.24							OK	OK
	68	31.558	36.4*	87.82	130.31*							OK	OK
	79	31.889	41.6	100.85	153.54							OK	OK
	$\bar{X}$	31.833	39.8	95.91	142.52							OK	OK

Yield 4/11, 2 others OK except V_3 Voltage Step-Up Ratio 130-145

* Failures

Table 7-2. First Submittal - 18mm Confirmatory Samples
B. Group II Test (Continued)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance Input (nf)	Capacitance V_{12} (pf)	Capacitance V_3 (pf)	Dissipation (Percent) Input	Dissipation (Percent) V_{12}	Dissipation (Percent) V_3	Solder-ability	Induced Voltage
Post Thermal Shock	30	31.736	39.2	93.48	137.11*								
	36	31.841	39.7	91.78	134.28*								
	57	31.843	35.80	80.45	116.15*								
	$\bar{X}$	31.807	38.23	88.57	129.18								
High Temp Storage	30	32.193	51.4	110.8	164.8								
	36	32.308	42.1	89.8	131.80*								
	57	32.439	51.70	102.30	146.60								
	$\bar{X}$	32.313	48.4	100.97	147.73								
Low Temp Storage	30	31.064	30.0	64.02	85.0							OK	
	36	31.160	31.10	62.32	82.72							OK	
	57	31.273	29.40	59.49	79.32							OK	
	$\bar{X}$	31.166	30.17	61.94	82.35							OK	
Post Resistance To Solder	30	32.073	50.3	102.0	147.3								OK
	36	32.273	48.40	91.80	133.10*						①		OK
	57	32.261	50.80	96.30	138.80*						①		OK
	$\bar{X}$	32.202	49.83	96.7	139.73								OK

① Case opened from solder heat.

Yield = 1/3, 2 others OK except V_3 Voltage Step-Up Ratio 130-145

* Failures

Table 7-2. First Submittal - 18mm Confirmatory Samples C. Group III Test (Continued)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance			Dissipation (Percent)			Visual Internal
						Input (nf)	V_{12} (pf)	V_3 (pf)	Input	V_{12}	V_3	
Post Thermal Shock	40	31.781	42.0	98.02	141.08*							
	43	32.020	44.5	99.72	150.71							
	44	31.762	39.6	87.82	129.70*							
	49	31.937	39.33	91.22	135.9*							
	50	32.013	43.50	104.25	156.37							
	55	32.047	43.7	104.25	146.74							
	58	31.857	39.0	88.39	131.44*							
	61	32.036	43.3	104.82	152.97							
	74	32.186	50.4	64.03*	95.75*							
	$\overline{X}$	31.960	42.81	93.61	137.85							
Life Test 2000 Hours	40	32.126	48.4	96.3	135.90*							
	43	32.433	52.80	100.3	152.9							
	44	32.099	48.80	93.50	137.7*							
	49	32.343	47.3	90.70	133.1*							
	50	32.386	50.2	104.8	158.6							
	55	32.618	58.8	120.1	168.8							
	58	35.715	12.7*	45.3*	212.5*							
	61	32.562	55.2	116.1	170.0							
	74	32.680	56.3	59.5*	90.7*							OK
	$\overline{X}$	32.774	47.83	91.84	151.13							

Yield = 4/9, 3 others OK except V_3 Voltage Step-Up Ratio 130-145

* Failures

Table 7-2. First Submittal - 18mm Confirmatory Samples D. Group IV Test (Concluded)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance			Dissipation (Percent)			Induced Voltage	Visual Internal
						Input (nf)	V_{12} (pf)	V_3 (pf)	Input	V_{12}	V_3		
Post Thermal Shock	31	32.106	39.5	92.35	146.20								
	38	32.179	49.7	118.41	175.65								
	45	32.114	42.60	97.450	139.94*								
	46	31.722	41.40	91.22	134.84*								
	48	31.898	45.5	101.42	147.31								
	52	31.708	39.2	95.75	135.98*								
	60	31.498	31.1*	81.02*	118.98*								
	$\overline{X}$	31.889	41.29	96.80	142.70								
Post Vibration	31	32.330	59.40	59.50*	91.20*								
	38	32.620	54.70	111.0	166.6								
	45	32.528	45.2	90.6	128.6*								
	46	32.157	49.2	91.8	138.2*								
	48	32.263	49.6	97.4	140.5*								
	52	32.271	55.4	115.0	161.5								
	60	32.003	47.0	95.7	142.2*								
	$\overline{X}$	32.382	51.5	94.43	138.4								
Post Mechanical Shock	31	32.791	58.1	57.80*	87.80*							OK	
	38	32.622	59.0	118.4	176.20							OK	
	45	32.560	47.0	95.2	134.8*							OK	
	46	32.190	47.4	88.9	135.4*							OK	OK
	48	32.679	49.0	24.4*	237.4*							OK	OK
	52	32.303	57.5	119.5	167.7							OK	
	60	32.083	49.5	100.3	146.2							OK	
	$\overline{X}$	32.461	52.5	86.36	155.07							OK	OK

Yield = 3/7, 2 others OK except V_3 Voltage Step-Up Ratio 130-145

* Failures

Seven units had at least one functional voltage output but did not meet both output requirements after thermal shock. Two of these units improved with age sufficiently to be within specification later in the test sequence. Thus, it is apparent that aging of the ceramic element improves performance of the PET and decreases the impact of thermal shock. Note, for instance, that most of the lower numbered units built earlier passed the thermal shock test.

The 25mm assembly and bonding of the four ceramic elements proved to be a time-consuming and unreliable process. The unproven, lower cost approach proposed for the confirmatory build whereby the top case was used as the bonding fixture was not workable. The case did not give adequate support to the first element inserted in the package and the set-up time of the epoxy was too short. This resulted in cracking of the first element and poor control of the bond thickness between elements. Improvements in the thickness control of the bond was obtained by bonding three elements in an external bonding fixture and then bonding these to the first element in the package. However, of the 40 units made by this process, only 18 satisfactory units were obtained. Cracking of elements was the main cause of failure. Further efforts were made to improve the process for the final build of 25mm confirmatory units by reverting back to the earlier process where a bonded pair was used to drive each of the V_{12} and V_3 outputs (no bonding between pairs). Fourteen such PETs were built to go with the 18 units built earlier. Thirty of these 25mm units were submitted for the first submittal units.

As shown in Table 7-1, most tests of the first submittal 18mm PETs that were 100 percent acceptable were also 100 percent acceptable with the thirty 25mm PETs that were evaluated. For instance, terminal strength, solderability, induced voltage and resistance to barometric pressure were not a problem with either unit. However, primary and secondary capacitance and other electrical properties were significantly out of specification. All units failed the ambient 50 percent efficiency requirement. As shown in Table 7-3, the 25mm PETs were in the 35 to 45 percent range. However, at -45°C, eleven 25mm PETs met the 20 percent specification requirement and the voltage step-up ratio. In fact, at low temperature, 23 units met the voltage step-up with efficiencies of 15 to 23 percent.

Most of the electrical problems appear to be related to the thermal shock tests. Only 2 of the 30 units met the 165 voltage step-up ratio requirement after thermal shock. It is speculated that units are cracked or leads broken by the high thermal stresses associated between the epoxy bonded ceramic elements. The fragile nature of this approach is also borne out by fracture of the units in the mechanical shock tests. The fact that one unit, S/N 34, passed both mechanical vibration and shock indicate that the approach can be made to work. However, reliability of the bonding approach makes the process for the 25mm PETs too costly to be considered further.

Table 7-3. First Submittal - 25mm Confirmatory Samples A. Group I Test

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance Input (nf)	Capacitance V_{12} (pf)	Capacitance V_3 (pf)	Dissipation (Percent) Input	Dissipation (Percent) V_{12}	Dissipation (Percent) V_3	Terminal Strength	Induced Voltage
Post Thermal Shock	30	29.920	37.9*	134.8*	135.6*	37.060	13.0	12.0	0.57	--	--	OK	OK
	32	29.704	32.6*	127.2*	125.6*	27.050	17.5	17.0	0.65	1.0	2.0	OK	OK
	35	29.745	40.8*	140.0*	150.4*	35.120	13.0	12.0	0.55	--	--	OK	OK
	39	29.924	40.4*	135.6*	134.8*	38.430	15.0	14.0	0.56	--	--	OK	OK
	40	30.218	37.0*	140.4*	142.8*	37.850	16.7	16.1	0.69	1.0	1.0	OK	OK
	48	30.020	43.1*	153.6*	152.8*							OK	OK
	52	29.789	39.5*	154.0*	160.0*	38.120	14.80	15.9	0.50	1.0	2.0	OK	OK
	55	30.072	44.7*	167.2	163.2*							OK	OK
	59	30.343	36.6*	140.0*	137.6*	28.060	16.0	16.1	0.66	--	--	OK	OK
	67	30.020	22.1*	111.6*	111.6*	28.240	15.0	14.8	0.67	--	--	OK	OK
	71	30.120	38.6*	123.6*	124.4*							OK	OK
	$\bar{X}$	29.99	37.39	138.91	139.89								

Yield = 0/11

* Failures

Table 7-3. First Submittal - 25mm Confirmatory Samples B. Group II Test (Continued)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance Input (nf)	Capacitance V_{12} (pf)	Capacitance V_3 (pf)	Dissipation (Percent) Input	Dissipation (Percent) V_{12}	Dissipation (Percent) V_3	Solderability	Induced Voltage
Post Thermal Shock	45	29.966	43.0*	136.0*	134.0*								
	49	29.948	42.0*	128.8*	126.0*								
	57	29.914	35.5*	127.6*	129.2*	26.96	16.5	16.0	0.55	--	--		
	$\bar{X}$	29.943	40.17*	130.8*	129.7*								
High Temp Storage	45	30.087	35.6*	163.6*	122.4*								
	49	30.142	38.8*	132.0*	129.2*								
	57	30.068	24.7*	114.4*	115.2*								
	$\bar{X}$	30.099	33.03*	136.7*	122.3*								
Low Temp Storage	45	28.891	19.0*	96.8	94.4							OK	
	49	29.000	18.0*	77.6*	73.6*							OK	
	57	29.131	20.3	78.4*	77.2*							OK	
	$\bar{X}$	29.007	19.1*	84.27	81.73								
Post Resistance To Solder	45	29.993	43.1*	142.8*	144.8*								OK
	49	30.055	28.9*	101.6*	74.4*								OK
	57	30.160	41.4*	144.8*	146.8*	26.10	16.2	16.0	0.44	--	--		OK
	$\bar{X}$	30.069	37.8*	129.73*	122.0*								

Yield = 0/3

* Failures

Table 7-3. First Submittal - 25mm Confirmatory Samples
C. Group III Test (Continued)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance Input (nf)	Capacitance V_{12} (pf)	Capacitance V_3 (pf)	Dissipation (Percent) Input	Dissipation (Percent) V_{12}	Dissipation (Percent) V_3	Visual Internal
Post Thermal Shock	36	29.567	41.5*	147.2*	144.8*	37.60	18.9	12.8	0.50	--	--	
	37	29.957	39.7*	133.6*	134.4*							
	38	29.678	39.8*	147.6*	141.2*							
	41	29.716	39.6*	140.0*	135.6*							
	43	30.196	41.4*	140.8*	136.4*	38.95	3.0	3.0	1.00	--	--	
	44	30.001	44.7*	170.4	170.0							
	50	29.910	29.4*	151.6*	148.8*							
	54	30.004	40.9*	138.4*	134.8*							
	63	29.672	35.5*	131.2*	132.0*							
	$\bar{X}$	29.856	39.17*	144.53*	142.0*							
After Life Test 2000 Hours	36	30.335	30.2*	161.2*	54.8*							OK
	37	30.169	18.9*	76.8*	75.2*							
	38	29.075	14.7*	87.2*	82.0*							
	41	29.960	36.0*	129.5*	127.6*							
	43	30.238	24.4*	115.2*	114.0*	38.40	15.7	16.0	1.56	1.0	0	
	44	30.063	40.0*	144.0*	146.8*	35.63	17.0	16.6	0.55	--	--	
	50	29.937	25.1*	139.2*	139.2*	38.34	17.0	17.0	1.21	--	--	
	54	29.867	24.8*	130.4*	129.6*	36.69	16.0	16.2	0.78	--	--	
	63	29.882	33.8*	123.2*	130.0*							
	$\bar{X}$	29.947	27.54*	122.97	111.02							

Yield = 0/9

* Failures

Table 7-3. First Submittal - 25mm Confirmatory Samples
D. Group IV Test (Concluded)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance Input (nf)	Capacitance V_{12} (pf)	Capacitance V_3 (pf)	Dissipation (Percent) Input	Dissipation (Percent) V_{12}	Dissipation (Percent) V_3	Induced Voltage	Visual Internal
Post Thermal Shock	33	29.884	29.5*	152.0*	150.8*	38.74	13.7	14.0	0.62	1.0	2.0		OK
	34	29.681	33.9*	176.4	177.6	39.60	15.0	13.80	0.59	--	--		
	47	29.751	40.3*	128.4*	124.8*								
	53	29.699	31.6*	139.2*	131.6*								
	56	29.943	43.2*	132.8*	134.0*	35.61	17.9	17.3	0.66	2.0	1.0		
	61	29.610	26.8*	142.0*	136.0*	38.24	3.0	3.0	0.60	--	--		
	66	29.977	41.3*	160.0*	154.8*								OK
	$\bar{X}$	29.792	35.23*	147.26*	144.23*								
Post Mechanical Vibration	33	30.195	45.3*	176.4	175.2								
	34	29.983	48.1*	202.4	202.0								
	47	29.839	42.0*	146.4*	146.8*								
	53	30.040	19.7*	76.0*	56.8*								
	56	30.127	42.5*	143.6*	145.6*								
	61	30.211	6.0*	8.8*	90.8*								
	66	30.353	39.5*	114.8*	116.4*								
	$\bar{X}$	30.107	34.73*	124.06*	133.37*								
Post Mechanical Shock	33		No Output*										
	34	29.966	48.6*	208.0	206.4							OK	
	47	30.100	21.3*	107.6*	106.4*							OK	
	53		No Output*										
	56		No Output*										
	61		No Output*										
	66	29.628	14.4*	57.2*	56.4*							OK	
	$\bar{X}$	29.898	28.1*	124.27*	123.07*								

Yield = 1/7 at 45% Efficiency.

* Failures

There were also many problems connected with the small (p_) terminal, which did not survive the solder reheat test.

After considerable effort on the 25mm PETs, it was concluded that the cost associated with construction of these units would not justify their substitution for the presently used wire wound step-up transformers. It was mutually agreed that further effort on these transformers should be discontinued.

B. SECOND SUBMITTAL 18MM PET CONFIRMATORY SAMPLES

The 18mm units built in December 1976 and January 1977 and evaluated during the period from January through March were rejected by our Honeywell inspection group. After approval to complete the confirmatory build against the specification given in Section V, the rejected lot was examined and tested at room temperature. Twenty-one of the units first submitted (Table 7-1) performed better than the minimum required efficiency and step-up voltage ratio. Sixteen were faulty. Faulty units were disassembled, cleaned and repaired by resoldering leads to the ceramic, terminals, etc., to produce about 20 repaired packaged 18mm PETs. Eight of these also contained new, freshly polarized ceramic elements made from a new lot of K-9 PZ-PT (Batch 2592) and four were from the earlier K-9 material. These 41 units were again evaluated and 30 were selected for second confirmatory sample submitted.

The reworked second submittal group of 18mm PETs was evaluated during the period December 28, 1977 to January 26, 1978. Detailed data on these parts are given in Table 7-4. The 30 units evaluated met all specification requirements. Included in this group are six units which were recently polarized and three of the six were made from a more recent lot of K-9 PZ-PT. Note that all average data for resonant frequency and voltage step-up are well centered in the specified limits and that efficiency is significantly above the minimum value of 30 percent at room temperature and 15 percent at -54°C.

C. PILOT RUN

The pilot run produced 155 18mm PET assembled units during the period of February 20, 1978 to June 29, 1978. All elements assembled were polarized May 22-25, 1978. During assembly and half-pack testing (operation 160) only eight units were found which contained elements broken during packaging or with poor electrical connections.

After final assembly and testing, only three completed PETs were found with low voltage step-up ratios. These were deleted and an inspection lot of 153 units was submitted

Table 7-4. Second Submittal - 18mm Confirmatory Samples
A. Group I Test

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance			Dissipation (Percent)			Terminal Strength	Induced Voltage
						Input (nf)	V_{12} (pf)	V_3 (pf)	Input	V_{12}	V_3		
Post Thermal Shock	30[1]	32.125	46.6	108.0	161.6	13.655	6.0	6.0	0.85	--	--	OK	OK
	32	32.186	42.2	94.4	143.2	13.288	6.0	6.0	0.75	--	--	OK	OK
	33[1]	32.050	43.5	102.4	166.0	13.904	5.8	5.1	0.79	--	--	OK	OK
	34[1]	32.532	45.0	102.8	156.4	12.964	6.8	5.8	0.53	--	--	OK	OK
	37	32.306	54.0	122.8	188.8	13.853	5.7	5.5	0.49	--	--	OK	OK
	41	32.455	43.6	104.8	165.2	12.827	5.4	5.7	0.64	--	--	OK	OK
	46	32.092	40.5	86.4	136.4	13.113	6.8	6.0	0.87	--	--	OK	OK
	52[1]	32.308	50.0	116.8	171.6	14.184	5.9	5.9	0.82	--	--	OK	OK
	61[1]	32.706	53.6	126.4	192.4	13.426	5.7	6.0	0.43	--	--	OK	OK
	65	32.279	47.4	100.8	150.8	13.186	5.1	5.1	0.65	--	--	OK	OK
	68[1]	32.093	42.1	97.6	150.8	13.652	6.5	5.9	0.92	--	--	OK	OK
	79[1]	32.312	46.8	110.4	175.2	13.522	6.8	6.0	0.58	--	--	OK	OK
	80	32.084	45.3	116.0	180.0	14.712	6.0	5.5	1.41	--	--	OK	OK
	$\overline{X}$	32.271	46.2	106.9	164.5	13.560	6.0	5.7	0.75	--	--	OK	OK

Yield = 13/13

(1) First submittal samples resubmitted with no rework.

Table 7-4. Second Submittal - 18mm Confirmatory Samples
B. Group II Test (Continued)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance			Dissipation (Percent)			Solder-ability	Induced Voltage	Visual External	Visual Internal
						Input (nf)	V_{12} (pf)	V_3 (pf)	Input	V_{12}	V_3				
Post Thermal Shock	31	32.307	38.3	90.4	148.8	13.374	6.0	6.0	0.61	--	--				
	43[1]	32.593	49.6	105.2	166.4	12.735	5.5	5.1	0.70	--	--				
	69	31.784	40.8	96.0	145.2	14.055	6.8	6.0	1.30	--	--				
	$\overline{X}$	32.228	42.9	97.2	153.5	13.388	6.1	5.7	0.87						
High Temp Storage	31	32.507	42.6	102.8	171.2										
	43[1]	32.626	52.9	110.8	177.6										
	69	31.870	45.0	104.4	159.6										
	$\overline{X}$	32.334	46.8	106.0	169.5										
Low Temp Storage	31	31.168	21.1	48.0	75.3							OK			
	43	31.355	27.6	56.8	82.4							OK			
	69	30.998	26.8	59.2	84.0							OK			
	$\overline{X}$	31.174	25.2	54.7	80.6							OK			
Post Resistance To Solder	31	32.347	36.3	86.0	137.2								OK	OK	OK
	43	32.522	50.9	107.2	168.8								OK	OK	OK
	69	31.889	46.9	108.8	163.2								OK	OK	OK
	$\overline{X}$	32.253	44.7	100.7	156.4								OK	OK	OK

Yield = 3/3

(1) First submittal samples resubmitted with no rework.

Table 7-4. Second Submittal 18mm Piezoelectric Transformer, Confirmatory Samples
C. Group III Test (Continued)

	S/N	Resonant Frequency	Efficiency %	Step-Up V_{12}	Step-Up V_3	Capacitance Input (nf)	Capacitance V_{12} (pf)	Capacitance V_3 (pf)	Dissipation Input %	Dissipation V_{12} %	Dissipation V_3 %
Post-Thermal Shock 1/4/78	42	31.771	38.2	92.0	136.0	14.510	6.0	5.5	1.46	-	-
	44	32.108	42.0	90.8	138.0	13.242	6.0	5.4	.83	-	-
	48	32.011	42.7	100.4	160.8	14.070	6.4	5.5	1.13	-	-
	49	32.277	46.0	100.8	159.2	13.022	5.7	5.0	.78	-	-
	50[1]	32.424	48.1	112.0	174.8	13.445	6.4	5.6	.62	-	-
	54[1]	32.232	44.9	107.6	167.6	13.856	6.0	5.8	.75	-	-
	56	32.174	45.3	95.2	141.6	13.358	6.0	5.5	.80	-	-
	57[1]	32.308	48.1	102.8	153.6	12.667	7.0	5.8	.75	-	-
	74	32.352	38.9	91.6	144.4	13.997	5.3	5.1	.81	-	-
	$\bar{X}$	32.184	43.8	99.2	152.8	13.574	6.1	5.5	.88		
During Life (96 Hours) 1/7/78	42	31.717	49.0	89.6	132.0						
	44	32.076	40.0	88.0	133.6						
	48	31.949	39.6	94.4	150.8						
	49	32.279	45.2	100.0	156.8						
	50	32.390	45.7	106.0	164.0						
	54	32.130	40.3	96.0	150.0						
	56	31.981	40.1	84.8	130.1						
	57	32.272	45.4	97.6	145.6						
	74	32.085	37.7	86.8	131.2						
	$\bar{X}$	32.098	42.6	93.7	143.8						
During Life (240 Hours) 1/16/78	42	31.715	36.0	88.0	130.4						
	44	32.120	40.0	90.0	136.0						
	48	32.033	40.3	97.2	154.8						
	49	32.289	43.4	98.8	154.4						
	50	32.198	42.1	97.2	150.8						
	54	32.265	42.4	104.4	161.2						
	56	32.129	41.9	90.0	132.0						
	57	32.313	44.3	98.0	145.2						
	74	32.204	36.7	88.0	138.0						
	$\bar{X}$	32.141	40.8	94.6	144.7						
Post-Life (500 Hours) 1/26/78	42	31.869	39.6	94.8	138.8	14.307	6.0	5.5	1.22	-	-
	44	32.140	43.0	93.2	142.0	13.189	6.0	6.0	.77	-	-
	48	32.034	48.1	103.2	164.0	13.857	6.0	5.5	.97	-	-
	49	32.268	46.7	102.0	159.2	12.893	5.7	5.7	.65	-	-
	50	32.446	48.9	113.2	175.6	13.397	5.5	6.0	.58	-	-
	54	32.312	47.2	111.2	172.0	13.694	5.3	6.0	.69	-	-
	56	32.218	45.5	95.2	140.8	13.747	6.0	6.0	.73	-	-
	57	32.351	48.8	103.6	154.8	12.655	5.8	6.0	.67	-	-
	74	32.221	40.9	91.6	144.8	14.143	5.5	5.0	.84	-	-
	$\bar{X}$	32.206	44.3	99.6	152.5	13.486	5.8	5.7	.79	-	-

Yield = 9/9

[1] First submittal samples resubmitted with no rework

Table 7-4. Second Submittal - 18mm Confirmatory Samples
D. Group IV Test (Concluded)

	S/N	Resonant Frequency	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance			Dissipation (Percent)			Induced Voltage
						Input (nf)	V_{12} (pf)	V_3 (pf)	Input	V_{12}	V_3	
Post Thermal Shock	36	32,272	47.7	103.2	155.2	13,258	5.9	6.0	0.53	--	--	
	45[(1)]	32,511	48.7	113.6	167.6	13,751	5.8	5.9	0.52	--	--	
	47	32,106	46.2	100.8	149.2	13,695	5.7	5.8	0.87	--	--	
	51	32,457	52.4	126.8	192.0	13,445	6.0	6.6	0.46	--	--	
	55[(1)]	32,755	54.0	123.6	180.4	13,391	5.3	5.7	0.40	--	--	
	67[(1)]	32,548	51.7	123.6	191.2	13,204	6.3	5.8	0.44			
	$\bar{X}$	32,441	50.1	115.3	172.6	13,457	5.8	6.0	0.54			
Post Vibration	36	32,331	50.3	108.0	162.0							
	45	32,551	40.4	93.0	136.0							
	47	32,121	46.8	101.0	148.0							
	51	32,475	52.1	125.0	189.0							
	55	32,777	58.9	134.0	194.0							
	67	32,576	53.6	127.0	195.0							
	$\bar{X}$	32,472	50.4	114.7	170.7							
Post Mechanical Shock	36	32,314	53.1	113.2	168.8							OK
	45	32,512	55.0	126.8	186.8							OK
	47	32,134	51.3	110.4	163.2							OK
	51	32,487	55.5	131.6	198.0							OK
	55	32,771	57.7	133.4	196.4							OK
	67	32,615	49.8	118.0	182.4							OK
	$\bar{X}$	32,472	53.7	122.2	182.6							

Yield = 6/6

(1) First submittal samples resubmitted with no rework.

July 5, 1978. Tables 7-5 and 7-6 give the inspection results obtained for the quality conformance Group "A" and Group "B" tests.

Twenty units were evaluated at room temperature after the thermal shock test (Table 7-5). The average efficiency of these units was 42 percent with the voltage step-up ratio of V_{12} and V_3 outputs being 108 and 162, respectively, at a resonant frequency of 31.6 KHz.

Twelve units were evaluated for low and high temperature storage (Table 7-6a) of -52° and +52°C and found to have as average efficiencies of 28 and 35 percent; V_{12} ratio of 67 and 96; and V_3 ratio of 100 and 142, respectively. All of these were within specification.

Twenty-five units received the specified vibration and mechanical shock-testing (Table 7-6b) with the post behavior of 40 and 42 percent for efficiency; 104 and 108 for V_{12} step-up ratio and 155 and 160 V_3 step-up ratio, respectively. No malfunctions occurred in the units during vibration and all units passed induced voltage test.

Nine units received 500 hours of life testing without malfunctioning (Table 7-6c). The efficiency and voltage step-up ratio of all units increased during these tests. The five units evaluated for resistance to solder reheat, solderability, terminal strength and internal construction (Table 7-6d) were all satisfactory. Government on-site inspection verified that all tests were satisfactorily met, and 150 units were packaged and submitted to NV and EOL at Fort Belvoir on August 8, 1978, to complete the pilot run.

The problem encountered in the 18mm PET confirmatory build part of this program were resolved. All units met the required specifications. This was verified by Howard Kessler of Fort Belvoir on February 13, 1978, and by Sol Bremmer of Fort Belvoir on March 7, 1978. Approval of the confirmatory samples and approval to start the pilot production run of 150 18mm PETs was received March 22, 1978.

Table 7-5. Pilot Run Quality Conformance Group A Inspection Results

	S/N	Resonant Freq.	Efficiency (Percent)	Step-Up V_{12}	Step-Up V_3	Capacitance			Dissipation (Percent)			Visual (External)	S/N	Induced Voltage
						Input (nf)	V_{12} (pf)	V_3 (pf)	Input	V_{12}	V_3			
Post-Thermal Shock	106	31.679	38.9	104.4	164.4	14.89	4.6	4.6	0.65	0	0	OK	110	OK
	116	31.558	32.3	92.4	145.2	15.41	5.3	5.0	0.66	0	0	OK	114	OK
	126	31.523	38.9	108.8	170.0	15.88	5.4	5.0	0.66	0	0	OK	123	OK
	138	31.564	38.6	106.4	164.4	15.69	5.0	5.0	0.59	0	0	OK	127	OK
	139	31.868	42.7	108.0	164.4	14.50	5.0	5.0	0.63	0	0	OK	133	OK
	148	31.717	52.4	112.0	164.4	15.38	5.0	5.0	0.61	0	0	OK	141	OK
	154	31.760	43.1	111.2	162.0	14.17	5.6	5.6	0.65	0	0	OK	152	OK
	164	31.803	44.9	113.2	161.2	14.89	5.0	5.3	0.53	0	0	OK	159	OK
	186	31.723	43.1	110.0	165.2	15.71	5.1	5.0	0.61	0	0	OK	162	OK
	197	31.524	38.7	104.4	162.8	15.69	5.3	5.1	0.55	0	0	OK	169	OK
	210	31.720	39.9	110.8	167.6	15.04	5.0	5.3	0.57	0	0	OK	172	OK
	215	31.754	41.4	111.2	172.4	15.53	5.3	5.2	0.57	0	0	OK	177	OK
	222	31.455	40.1	110.4	165.2	15.33	5.4	5.3	0.67	0	0	OK	184	OK
	237	31.547	42.0	103.2	160.0	14.83	5.6	5.3	0.56	0	0	OK	196	OK
	238	31.640	56.1	120.0	173.2	15.36	5.4	5.4	0.62	0	0	OK	204	OK
	245	31.686	44.6	106.0	153.2	14.74	5.0	5.0	0.55	0	0	OK	214	OK
	248	31.534	40.2	103.6	153.2	14.98	5.7	5.7	0.59	0	0	OK	224	OK
	257	31.710	42.3	105.6	167.6	14.64	6.0	5.2	0.55	0	0	OK	235	OK
	273	31.520	42.3	105.6	153.2	15.19	5.4	5.4	0.60	0	0	OK	240	OK
	274	31.481	40.9	104.0	152.8	15.59	5.1	5.3	0.62	0	0	OK	246	OK
	$\overline{X}$	31.638	42.2	107.6	162.1	15.17	5.3	5.2	0.60	0	0	OK	251	OK

Table 7-6. Pilot Run Quality Conformance Group B Inspection Results - Subgroup 1

	S/N	Resonant Freq.	Efficiency (Percent)	Step-up V_{12}	Step-up V_3
High-Temperature Storage	125	31.521	30.1	84.0	132.0
	128	31.510	36.1	92.4	134.8
	146	31.618	36.7	96.0	140.0
	147	31.362	35.1	97.6	139.2
	150	31.531	35.2	104.0	156.8
	155	31.592	33.4	92.8	140.8
	160	31.888	38.8	106.0	158.4
	174	31.332	36.2	99.2	146.0
	180	31.629	36.2	99.6	147.6
	190	31.477	35.2	95.2	138.4
	193	31.724	36.2	96.4	136.4
	211	31.531	33.3	91.2	134.0
	$\overline{X}$	31.560	35.2	96.2	142.0
Low-Temperature Storage	125	31.133	25.3	63.6	100.8
	128	30.916	29.5	65.2	95.6
	146	31.038	30.9	71.6	104.8
	147	30.786	27.0	66.8	99.6
	150	31.032	27.6	67.2	102.4
	155	30.762	27.8	64.4	96.8
	160	31.171	28.7	68.0	99.6
	174	30.770	29.1	69.6	103.2
	180	30.947	29.0	69.6	103.2
	190	31.966	26.6	64.0	99.2
	193	31.195	28.3	66.0	94.4
	211	31.025	27.3	66.0	97.6
	$\overline{X}$	31.062	28.1	66.8	99.8

Table 7-6. Pilot Run Quality Conformance Group B Inspection Results - Subgroup 2 (Continued)

	S/N	Resonant Freq.	Efficiency Percent	Step-Up V_{12}	Step-Up V_3	Induced Voltage
Post-Vibration	110	31.694	35.7	100.8	158.0	
	114	31.765	37.8	104.0	156.4	
	123	31.659	36.5	98.0	150.4	
	127	31.815	41.7	111.2	170.0	
	133	31.697	44.5	114.8	161.2	
	141	31.489	39.1	102.8	159.2	
	152	31.951	33.8	86.8	132.4	
	159	31.560	31.7	91.2	138.0	
	162	31.485	40.3	111.6	161.2	
	169	31.580	40.8	101.6	158.4	
	172	31.670	44.6	108.8	154.4	
	177	31.776	41.4	103.2	149.2	
	184	31.923	48.7	122.0	169.2	
	196	31.620	40.4	101.6	154.8	
	204	31.735	44.5	110.8	166.0	
	214	31.607	37.9	100.0	136.0	
	224	31.539	43.0	106.4	158.4	
	235	31.706	40.2	102.4	153.6	
	240	31.837	37.0	100.8	153.6	
	246	31.578	37.6	96.0	143.6	
	251	31.683	40.6	100.4	144.8	
	254	31.650	43.4	108.0	160.8	
	258	31.631	39.4	100.0	150.8	
	266	31.679	43.1	110.4	158.0	
	275	31.571	41.2	110.0	175.2	
	$\overline{X}$	31.676	40.2	104.1	154.9	
Post-Mechanical Shock	110	31.720	37.3	104.0	160.4	OK
	114	31.809	39.7	109.6	164.0	OK
	123	31.730	40.3	108.0	164.8	OK
	127	31.827	42.6	113.2	175.2	OK
	133	31.716	45.5	116.0	160.8	OK
	141	31.609	41.5	109.2	168.8	OK
	152	31.999	35.4	90.8	139.2	OK
	159	31.653	31.5	90.0	137.6	OK
	162	31.522	42.7	116.8	166.4	OK
	169	31.606	43.7	108.0	169.2	OK
	172	31.697	47.4	115.2	162.4	OK
	177	31.819	46.3	113.6	163.6	OK
	184	31.960	51.9	128.4	177.6	OK
	196	31.657	43.6	109.6	165.2	OK
	204	31.723	42.4	103.6	155.2	OK
	214	31.615	40.7	108.4	149.6	OK
	224	31.558	43.1	105.6	155.2	OK
	235	31.492	40.2	102.0	152.4	OK
	240	31.861	39.4	106.8	161.6	OK
	246	31.609	39.0	98.8	148.0	OK
	251	31.708	40.4	98.4	140.4	OK
	254	31.695	45.7	112.4	166.0	OK
	258	31.651	41.8	105.6	159.2	OK
	266	31.688	44.5	112.4	159.2	OK
	275	31.576	43.4	113.6	178.0	OK
	$\overline{X}$	31.700	42.0	108.0	160.0	OK

Table 7-6. Pilot Run Quality Conformance Group B Inspection Results - Subgroup 3 (Continued)

	S/N	Resonant Freq.	Efficiency (percent)	Step-Up V_{12}	Step-Up V_3	Input (nf)	V_{12}	V_3	Input	V_{12}	V_3	Induced Voltage	Visual (External)
Life Test (96 hrs.)	120	31.470	34.8	102.4	155.2								
	149	31.391	32.3	88.4	130.4								
	157	31.541	31.6	83.2	128.4								
	171	31.412	33.8	91.2	140.0								
	227	32.086	32.9	90.0	135.2								
	232	31.520	38.5	102.0	142.8								
	241	31.790	32.5	87.6	143.2								
	269	31.273	31.1	92.8	134.4								
	276	31.553	32.5	96.0	150.4								
	$\overline{X}$	31.560	33.3	92.6	140.0								
Life Test (240 hrs.)	120	31.583	36.4	105.2	159.6								
	149	31.454	34.4	94.4	139.2								
	157	31.630	33.4	86.4	133.6								
	171	31.412	33.7	91.6	141.6								
	227	32.224	36.8	97.6	147.2								
	232	31.568	39.8	104.0	146.0								
	241	31.792	34.0	90.4	148.0								
	269	31.380	33.2	97.6	142.0								
	276	31.600	32.6	94.8	148.4								
	$\overline{X}$	31.627	34.9	95.8	145.1								
Lost Life (After 800 hrs.)	120	31.595	37.2	104.8	160.0	15.59	5.0	5.4	0.65	0	0	OK	OK
	149	31.576	34.1	98.4	148.0	15.97	5.1	5.0	0.71	0	0	OK	OK
	157	31.684	34.7	88.4	138.0	15.08	5.0	4.6	0.79	0	0	OK	OK
	171	31.569	37.2	98.4	153.2	15.36	5.7	5.3	0.73	0	0	OK	OK
	227	32.220	38.4	100.0	152.0	14.46	4.3	4.7	0.69	0	0	OK	OK
	232	31.629	40.5	105.2	148.0	15.74	5.0	5.0	0.67	0	0	OK	OK
	241	31.853	35.9	95.2	157.6	15.41	5.0	4.6	0.64	0	0	OK	OK
	269	31.445	35.0	101.2	148.4	16.21	5.4	5.4	0.53	0	0	OK	OK
	276	31.693	33.9	97.2	155.2	15.65	5.0	5.0	0.76	0	0	OK	OK
	$\overline{X}$	31.696	36.3	98.8	151.2	15.50	5.1	5.0	0.69	0	0	OK	OK

Table 7-6. Pilot Run Quality Conformance Group B
Subgroup 4 (Concluded)

	S/N	Resonant Freq.	Efficiency (percent)	Step-Up V_{12}	Step-Up V_3	Solderability	Terminal Strength	Visual (Internal)
Post-Resistance to Solder	122	31.581	36.4	97.6	136.0	OK	OK	OK
	130	31.340	37.2	108.4	160.8	OK	OK	OK
	167	31.626	39.5	107.6	149.2	OK	OK	OK
	176	31.688	36.0	107.6	154.0	OK	OK	OK
	188	31.770	43.1	116.8	166.4	OK	OK	OK
	$\overline{X}$	31.601	38.4	107.6	153.3	OK	OK	OK

SECTION VIII
PROCESS SUMMARY

Table 8-1 gives a summary of the four 18mm PET manufacturing procedures used in the pilot production run and the primary operations associated with each procedure. It shows that the 150 units shipped were produced over a period of about three months with 263 hours of production assembly labor, 72 hours of production machinist labor and 80 hours of inspection labor. In addition, about 80 hours of development technician, production engineering and quality engineering were used. Total direct cost of this labor was about $5, 400 and the material used cost about $700. Actual hours required to produce the pilot production run for each operation and the production yield are given in Table 8-1.

There was sufficient production capacity developed with the tooling and existing equipment available to meet the government's requirements for 400 PETs per month. The general report on this program will go into greater detail on the cost of the tooling developed and the additional cost associated with expanding the capacity to 2000 PETs/month. All tooling developed on this contract is owned by Honeywell, but because it was developed and built on this contract, its availability for government production contracts will be maintained at a no cost basis for four years (through 1983).

It is clear from Table 8-1 that about 75 percent of the time required for manufacturing the PET is in packaging and assembly of the piezoelectric ceramic element into the package. While the processes developed work satisfactorily, new efforts are required to develop more cost-effective approaches to packaging piezoelectric transformers.

Table 8-1. Pilot Production Results for 18mm

Procedure	Operation No.	Operation Description	Yield (%)	Completion Date	Time Required (hours)	Type Personnel
A		K-9 PZ-PT Prep	100	3/15	16.0	Assembly
B	010	Press K-9 Slugs	100	3/28	3.0	Assembly
	020	Hot Press Slugs	100	4/5	3.0	Assembly
	030	Grind Slugs	100	4/6	5.0	Machinist
	040	Core Drill Slugs	100	4/7	8.5	Machinist
	050	Hone Slugs	75	4/12	11.0	Machinist
	060	OD Grind Slugs	100	4/15	4.5	Machinist
	070	Mount and Slice	83	5/3	13.0	Machinist
	080	Clean Elements	99	5/8	3.0	Assembly
	090	Insp. Elements	91	5/9	1.0	Inspection
	100	Silver Elements	99	5/11	11.0	Assembly
	110	Silver Fire	95	5/12	4.0	Assembly
	120	Polarize	92	5/24	24.2	Assembly
	130	Polarity Check	100	5/25	1.0	Inspection
C	010	Injection Molding	75	4/15	16.0	Assembly
	020	Gate Removal	88	5/25	24.0	Machinist
D	140A	Top Case Prep	100	6/19	25.0	Assembly
	140B	Base Case Prep	100	6/2	13.5	Assembly
	150	Top Case Assembly	95	6/27	93.0	Assembly
	160	Electrical Check	98	6/28	6.0	Assembly
	170	Final Assembly	98	7/5	63.0	Assembly
	180	Inspection	100	8/7	78.0	Inspection

SECTION IX
RECOMMENDATIONS

Two additional efforts are required to make PETs cost-effective in the power supplies for night vision image intensifiers. First, a power supply which uses the PET approach needs to be fully developed. Initial development of a breadboard power supply in 1976[13] showed the feasibility of this approach, but additional effort is required to optimize this power supply for production. After this is shown to be feasible and cost-effective, additional efforts on the packaging of PETs need to be performed or made a part of the power supply package to reduce the high packaging cost associated with the PETs produced in this contract.

SECTION X
CONCLUSIONS

The 18mm PET production approach established by this program produced acceptable units which met all of the specifications established for this high voltage, step-up transformer. A one element packaged PET was established in place of the original two-element developmental units. This was accomplished by establishing more realistic resistive and capacitive load requirements for each of the V_{12} and V_3 voltage outputs.

All of the equipment and tooling designed and built produced satisfactory pilot production run units. The cost objectives were achieved on the individual piezoelectric elements. Higher costs were associated with attaching leads to the PET ceramic elements, and packaging was more time-consuming than desired.

SECTION XI

PUBLICATIONS AND REPORTS

During this contract, a paper on piezoelectric transformer design was presented at the American Ceramic Society Electronics Division Fall meeting in Dallas, Texas, September 17-20, 1978. This meeting was conducted in conjunction with the IEEE Committee on ferroelectricity. The authors, title and abstract of this paper are given below. This paper will be published in a future American Ceramic Society publication.

Title:	Relationship of Piezoelectric Properties to High Voltage Transformer Performance
Authors:	W. B. Harrison and U. Bonne
Abstract:	The influence of various changes in piezoelectric material parameters on the high voltage step-up, efficiency and applied electrical load behavior of piezoelectric transformers is reviewed. This information is based on a described, well-established math model which can predict transformer performance.

SECTION XII
IDENTIFICATION OF PERSONNEL

During this program, the following personnel worked the indicated hours in the area of responsibility given below.

Individual	Responsibility	Hours
W. B. Harrison	Program Manager	649
W. H. Kammeyer	Production Engineer Ceramic Manufacture and PET Assembly	306
G. O. Hendrickson	Metallurgical Engineer Interconnections	88
T. Rudy	Plastic Engineer PET Package Design	249
L. F. Hiltner	Quality Engineer	66
M. P. Murphy	Ceramic Technician Ceramic Manufacturing	550
M. R. Sandberg	Ceramic Technician Package Assembly	475
R. Larson	Plastic Technician	225
T. Lepsche	Development Engineer Interconnection	71
R. Ripley	Insp. PET Testing	270
E. Jackman	Instrumentation Technician Life Test Circuits	179
R. Keil	Electronics Engineer PET Test Console Design	99
R. Bohlken	Electronics Technician Test Console Build	250
P. Schansberg	Instrumentation Tech. Life Test Circuit Build	90
R. Erickson	Drafting	34
Miscellaneous	Production Tooling	1218 191

REFERENCES

1. W. G. Cady: "Piezoelectric Resonator," U.S. Pat. 17,359, assigned to RCA, July 2, 1929.

2. C. A. Rosen, et al: "Electromechanical Transducer," U.S. Pat. 2,830,274, assigned to GE, April 8, 1958.

3. H. W. Katz: "Solid State Magnetic and Dielectric Devices," John Wiley and Sons, Inc., NY (1959) p. 170ff.

4. C. A. Rosen: "Electrical Conversion Apparatus," U.S. Pat. 2,975,354, assigned to GE, March 14, 1961.

5. H. W. Schafft: "Piezoelectric Voltage Transforming Device," U.S. Pat. 3,397,328, assigned to Motorola, October 25, 1966.

6. H. W. Schafft: "Voltage Generation Utilizing Piezoelectric Effects," U. S. Pat. 3,397,328, assigned to Motorola.

7. N. Rudnick: "Solid State High Voltage Transformer," Gulton Ind. USAECOM - Ft. Belvoir, Va. Contract DAAK 02-69-C-0080.

8. "Development of a Piezoelectric Transformer," Final Report, Gulton Ind. USAMERDC Contract No. DAAK 02-71-00063.

9. W. B. Harrison and U. Bonne: "Design, Fabrication and Delivery of Ten Piezoelectric Transformers," Honeywell Inc. USAMERDC Contract No. DAAK 02-71-C-0064, Final Report, Jan. 10, 1972.

10. W. B. Harrison and U. Bonne: "Prototype Piezoelectric Ceramic, Voltage Step-Up Transformer" Honeywell Inc., Proposal Submitted to USAMERDC in response to RFQ DAAK02-72-Q-0336, Nov. 5, 1971.

11. "Design and Fabrication of Current Piezoelectric Transformers," Honeywell Inc., Proposal Submitted to USAMERDC in Response to RFQ DAAK 02-72-Q-0594, December 1, 1971.

12. W. B. Harrison and J. T. Lingle: "Prototype Piezoelectric Ceramic Voltage Step-Up Transformer," Contract DAAK02-72-C-0298, Vol. I and II.

13. J. T. Lingle "Product Improved Long Life 18mm Micro-Channel Wafer Image Intensified Tube Power Supply" Honeywell Inc. USAECOM Contract No. DAAG53-75-C-0217.

APPENDIX A

HONEYWELL-RECOMMENDED SPECIFICATION FOR PIEZOELECTRIC CERAMIC HIGH VOLTAGE TRANSFORMERS

1.0 SCOPE

1.1 Scope

This specification covers the requirements for voltage step-up transformers using piezoelectric ceramic materials which are manufactured by hot pressing techniques.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

The following documents of the issue in effect on the date of invitation for bid or request for proposal, form a part of this specification to the extent specified herein:

Specifications

Military

MIL-T-27 - Transformers and Inductors, General Specification For.

MIL-Q-9858 - Quality Program Requirements.

Standards

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.

MIL-STD-130 - Identification Marking of U.S. Military Property.

MIL-STD-202 - Test Methods for Electronic and Electrical Component.

MIL-STD-456 - Electronic Parts, Date and Source Coding For.

3.0 REQUIREMENTS

3.1 Item Definition

The piezoelectric ceramic transformer (PET), shall be a solid state electronic device which when driven at its resonant frequency by a regulated oscillator shall provide two separate appropriate A.C. voltage step-up ratios for powering parallel type voltage multipliers for operating image intensifier tubes. The PET shall consist of one element mounted in a plastic case (see Figure 1).

3.2 Materials

The PET shall consist of a single ceramic element. A $PbTiO_3$ - $PbZrO_3$ material must be selected to meet the electrical and mechanical requirements specified herein. Other materials selected for mounting and packaging the element into the PET shall be as specified herein and in accordance with MIL-T-27.

3.3 Physical Characteristics

The physical characteristics of the PET shall be as specified herein and in accordance with Figure 1. The weight requirement shall be 5 grams maximum (see 4.5.2).

3.4 Resistance to Soldering Heat

The PET shall show no evidence of mechanical or electrical damage after immersion in a molten solder pot at 240°C for 5 seconds (see 4.5.6). The PET shall meet the resonant efficiency at resonance (3.8.2) and voltage step-up (3.8.3) after subjection to resistance to soldering heat.

3.5 Solderability

The PET shall be solderable (see 4.5.9).

3.6 Terminal Strength

The PET shall show no evidence of loosening of the terminals, or other mechanical damage, when a pull of 1/2 pound is applied (see 4.5.7).

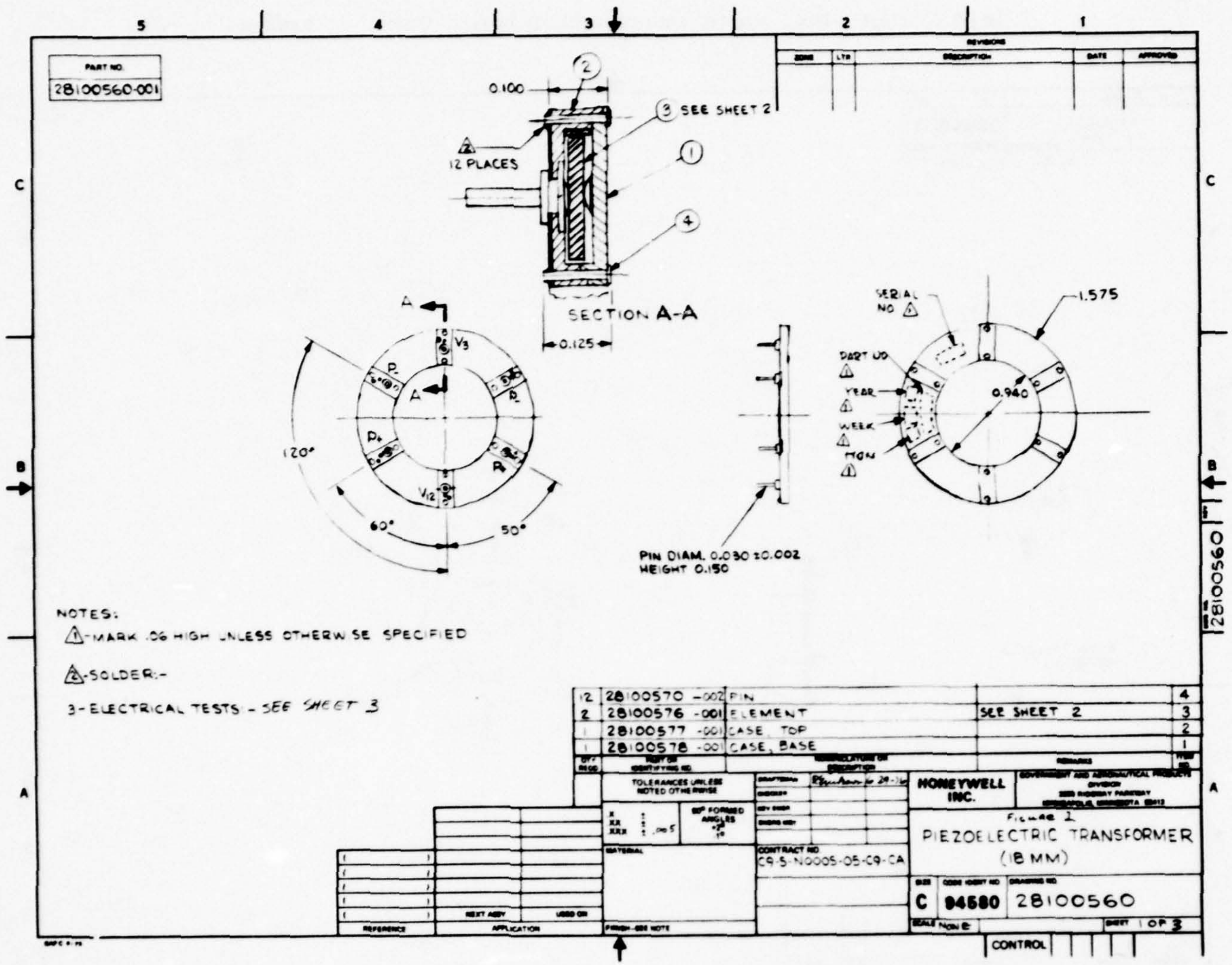


Figure 1. Construction Requirements for the 18mm PET (1 of 3)

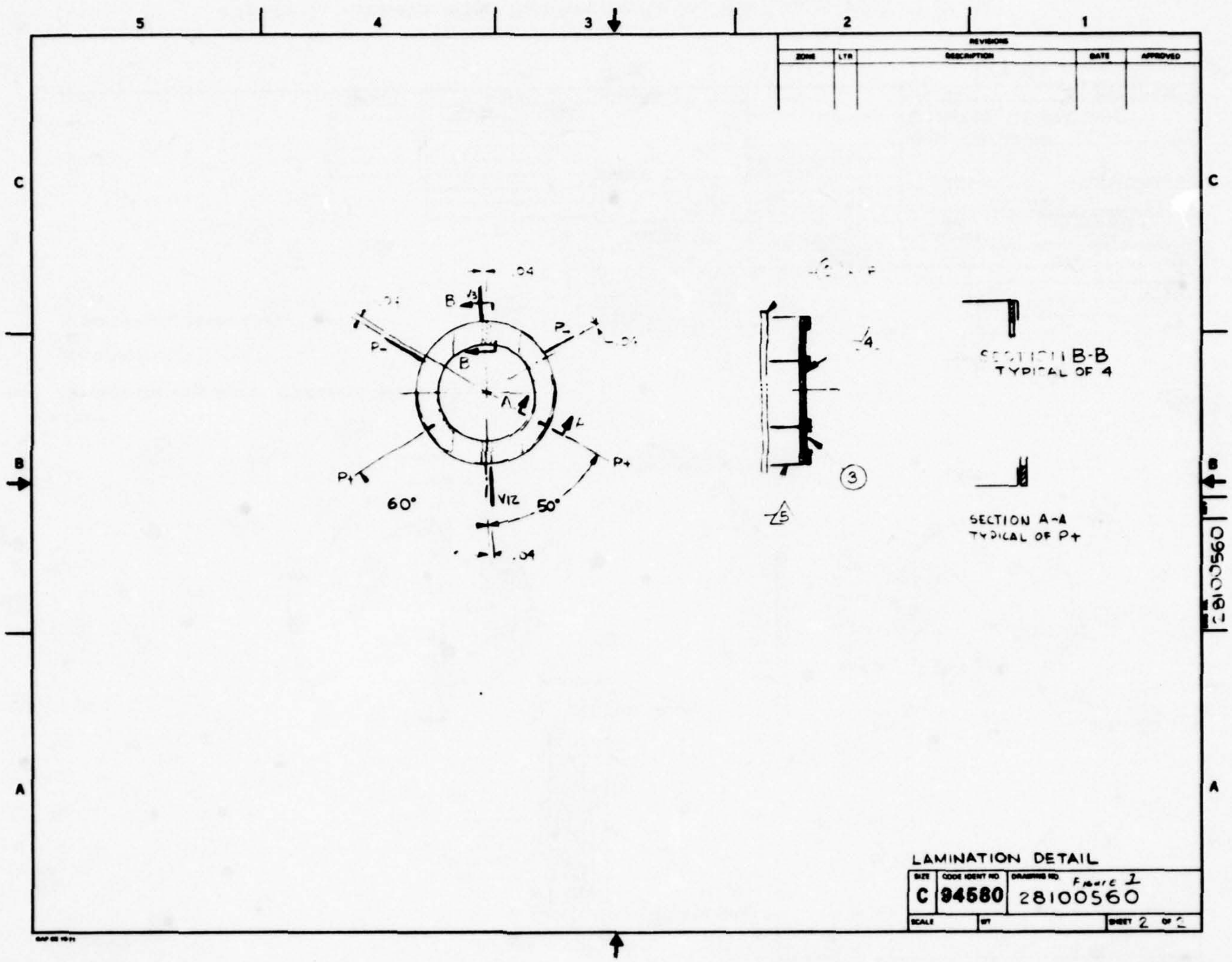


Figure 1. Construction Requirements for the 18mm PET (2 of 3)

ELECTRICAL REQUIREMENTS

When a 5 volt (p-p) sine wave input voltage to the PET is applied in parallel to the primary terminals (P_+ and P_-) and the ceramic is driven at its primary resonant frequency with the electrical load on the V_{12} secondary terminal of 2 megohms and 8 pf, and V_3 terminal of 100 megohms and 3 pf, the packaged units shall meet the following electrical requirements.

Resonant Frequency:

22 ± 2°C	32. 3 ± 1. 6 kHz
52 ± 2°C	32. 5 ± 1. 6 kHz
-54 ± 2°C	31. 6 ± 1. 6 kHz

Stepup Voltage	V_{12} output/input voltage	V_3 output/input voltage
22 ± 2°C	107 ± 27	173 ± 43
52 ± 2°C	107 ± 27	173 ± 43
-54 ± 2°C	58 ± 14	90 ± 18

Percent Efficiency

$$\frac{\frac{V_{12}^2}{R_{12}} + \frac{V_3^2}{R_3}}{V_{in} \quad I_{in}} \times 100$$

22 ± 2°C	30% min.
52 ± 2°C	30% min.
-54 ± 2°C	15% min.

Capacitance and Dissipation Factor: The input and output capacitance shall be measured at a nominal voltage and drive of 1 volt and 1 kHz.

Input Capacitance at Room Temperature		14 ± 1. 4 nf
Secondary Capacitance at Room Temperature	V_{12} and V_3	10 pf max.
Input Percent Dissipation at Room Temperature		1. 5% max.
Secondary Percent Dissipation at Room Temperature	V_{12} and V_3	1. 5% max.

The package PET unit must meet the requirements as described herein for solderability, resistance to solder heat, terminal strength, induced voltage, thermal shock, high and low temperature storage, humidity, mechanical shock and vibration, reduced barometric pressure, life and workmanship.

Electrical Requirements

Size	Code Ident No.	Drawing No.
C	94580	28100560
		Sheet 3 of 3

Figure 1. Construction Requirements for the 18mm PET (3 of 3)

3.7 Induced Voltage

The PET shall show no evidence of continuous arcing or breakdown nor shall there be an abrupt change in input current when a voltage is applied to the primary sufficient to cause 150 percent of the rated input voltage; i.e., 7.5 volts (p-p) (see 4.5.8).

3.8 Electrical Performance

The PET shall meet the requirements given in Figure 1.

3.9 Thermal Shock

The PET shall show no evidence of mechanical or electrical damage after subjection to thermal shock (see 4.5.13).

3.10 High Temperature Storage

The PET shall show no evidence of mechanical or electrical damage after subjection to a temperature of 71°C for a minimum of 8 hours (see 4.5.14).

3.11 Low Temperature Storage

The PET shall show no evidence of mechanical or electrical damage after subjection to storage at a temperature of -65°C for a minimum of 2 hours (see 4.5.15).

3.12 Mechanical Shock

There shall be no evidence of mechanical damage after subjection to mechanical shock (see 4.5.12).

3.13 Mechanical Vibration

The assembly with operating voltage applied shall not be damaged or suffer degradation of performance when subjected to simple harmonic motion parallel to and perpendicular to the radial axis over a frequency range of 10 to 55 Hz at a constant 2.5 g's for a period of two minutes in each plane (see 4.5.11).

3.14 Life

The PET voltage step-up at resonant frequency shall not decrease greater than 2 percent nor increase greater than 4.5 percent from the initial measurement during and after subjection to an elevated temperature of 52°C for 500 hours of operation. The PET shall meet the induced voltage (4.5.8), resonant frequency (4.5.3.1), efficiency at resonance (4.5.3.2), input capacitance and dissipation factor (4.5.3.4), and secondary capacitance and dissipation factor (4.5.3.5) after subjection to an elevated temperature of 52°C for 500 hours of operation (see 4.5.10).

3.15 Identification and Marking

The PET shall be marked in accordance with MIL-STD-130 with the manufacturer's name or code symbol, terminal identification, and date code in accordance with MIL-STD-436. Terminal and part number identification shall be in accordance with Figure 1.

3.16 Workmanship

The PET's shall be processed in such a manner as to be uniform in quality and appearance (see 4.5.2).

4.0 QUALITY ASSURANCE PROVISIONS (TEST PROCEDURES)

4.1 Responsibility for Inspection

Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, which is acceptable to the government. The government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Classification of Inspection

The examination and testing of PETs shall be classified as follows:

a. Confirmatory build inspection (does not include preparation for delivery) (see 4.3).

b. Quality conformance inspection (does not include preparation for delivery) (see 4.4).

4.3 Confirmatory Build Inspection

4.3.1 The PET's shall be tested as specified in Table 1 in the order shown.

4.3.2 No failures shall be permitted.

4.4 Quality Conformance Inspection

4.4.1 Group A Inspection -- Group A inspection shall consist of the examination and tests specified in Table 2, in the sequence as shown.

4.4.1.2 Sampling Plan -- Statistical sampling and inspection shall be in accordance with MIL-STD-105 for general inspection II. The AQL shall be as specified in Table 2. of this specification. Major and minor defects shall be as defined in MIL-STD-105.

4.4.2 Group B Inspection -- Group B inspection shall consist of the tests specified in Table 3 of this specification in the sequence as shown. Group B inspection shall be performed on sample units that have been subjected to and have passed Group A tests unless it is more practical to select a separate sample from the Lot for Group B inspection.

4.4.2.1 Sampling Plan -- The sampling quantities for each type transformer shall be as specified in Table 3. No more than one failure shall be allowed for each respective subgroup.

4.4.2.2 Rejected Lots -- If an inspection lot is rejected, the contractor may rework it to correct the defects, or screen out the defective units, and resubmit the lot for inspection. Resubmitted lots shall be inspected using Group B inspection quantities and tests as shown in Table 3.

4.5 Method of Examination and Test

4.5.1 Inspection Conditions -- Test will be conducted in accordance with the test procedure specified herein. Unless otherwise specified, the following conditions shall apply.

a. Inspections and test shall be performed in accordance with the test conditions specified in the "GENERAL REQUIREMENTS" of MIL-STD-202.

Table 1. Confirmatory Sample Inspection

Group I (all sample units)
Visual and mechanical examination (external)
Thermal Shock
Resonant frequency
Efficiency at resonance
Voltage step-up at resonance
Input capacitance and dissipation factor
Secondary capacitance and dissipation factor
Terminal strength
Induced voltage
Group II (three sample units)
High-temperature storage
Low-temperature storage
Solderability
Resistance to soldering heat
Induced voltage
Visual and mechanical examination (external)
Visual and mechanical examination (internal)
Group III (nine sample units)
Life
Group IV (six sample units)
Mechanical vibration
Mechanical shock
Induced voltage

Table 2. Quality Conformance Group A Inspection

	AQL Percent Defective	
	Major	Minor
Thermal shock	0.65	--
Visual and mechanical examination (external)	0.65	--
Induced voltage	0.65	--
Resonant frequency	0.65	--
Efficiency at resonance	0.65	--
Voltage step-up at resonance	0.65	--
Input capacitance and dissipation factor	0.65	--
Secondary capacitance and dissipation factor	0.65	--

Table 3. Quality Conformance Group B Inspection

Subgroup 1 (12 sample units)
High-temperature storage
Low-temperature storage
Subgroup 2 (20 sample units)
Mechanical vibration
Mechanical shock
Induced voltage
Subgroup 3 (9 sample units minimum)
Life
Induced voltage
Visual and mechanical examination (external)
Subgroup 4 (5 sample units)
Solderability
Resistance to soldering heat
Terminal strength
Visual and mechanical inspection (internal)

b. Capacitance load to the PET shall be as indicated in Figure 1.

c. Resistive load to the PET shall be as indicated in Figure 1.

d. Test frequency shall be within ± 2 percent of the nominal value.

e. Applied voltage to the primary shall be 5 volts ± 1 percent peak to peak sine wave input.

f. All critical electrical parameters, (step-up voltage and percent efficiency) shall be measured on well aged PET's (minimum of 30 days after assembly). Data taken at shorter intervals may be extrapolated (based on aging curves) to the 30 day values.

4.5.2 Visual and Mechanical Examination --

4.5.2.1 External -- PET's shall be examined to verify that the physical dimensions, weight, and marking (see 3.15) are in accordance with the applicable requirement. The PET's shall be weighed with a balance having an accuracy of 0.2 grams.

4.5.2.2 Internal -- PET's shall be disassembled and examined to verify that the materials, internal lead wires, internal mounting, and workmanship are in accordance with the applicable requirements (see 3.3 and 3.16).

4.5.3 Room Temperature Electrical Performance (See 3.8) --

4.5.3.1 Resonant Frequency -- With rated voltage applied to the primary of the PET, the secondary voltage shall be measured while the supply frequency is varied over the specified frequency range with the primary voltage held constant. All resonant frequencies shall be noted. Measurements shall be performed at the load condition specified in Figure 1.

4.5.3.2 Efficiency at Resonance -- The PET shall be operated at resonance in accordance with 4.5.3.1. At the loads specified in 4.5.3.1 the primary A.C. current and secondary RMS voltage shall be measured. Efficiency at resonance shall be calculated as:

$$\frac{\dfrac{V_{12}^2}{R_{12}} + \dfrac{V_3^2}{R_3}}{V_{in} \quad I_{in}} \times 100$$

4.5.3.3 Voltage Step-Up at Resonance -- The PET shall be operated at resonance in accordance with 4.5.3.1. At the loads specified in 4.5.3.1, the voltage output at the secondary shall be measured. Voltage step-up at resonance of each output shall be calculated as:

$$\frac{V_{12}\text{ (Secondary)}}{V_{in}\text{ (Primary)}} \text{ and } \frac{V_{3}\text{ (Secondary)}}{V_{in}\text{ (Primary)}}$$

4.5.3.4 Input Capacitance and Dissipation Factor -- The input capacitance and dissipation factor for the PET shall be determined by a capacitance bridge or other suitable means at 1 volt RMS at 1 KHz applied between the 2 parallel primaries and the 2 parallel grounds.

4.5.3.5 Secondary Capacitance and Dissipation Factor -- The capacitance and dissipation factor of each secondary shall be determined by a capacitance bridge or other suitable means at 1 volt RMS at 1 KHz applied between the secondary and ground.

4.5.4 High Temperature Electrical Performance -- The PET shall be maintained for a minimum of 1 hour at a temperature of plus 52°C (see 3.8).

4.5.4.1 Resonant Frequency -- The resonant frequency shall be determined for operation at plus 52°C in accordance with 4.5.3.1.

4.5.4.2 Efficiency at Resonance -- The efficiency at resonance shall be determined for operation at plus 52°C in accordance with 4.5.3.2.

4.5.4.3 Voltage Step-Up at Resonance -- The voltage step-up at resonance shall be determined for operation at plus 52°C in accordance with 4.5.3.3.

4.5.5 Low Temperature Electrical Performance -- The PET shall be maintained for a minimum of 1 hour at a temperature of minus 54°C (see 3.8).

4.5.5.1 Resonant Frequency -- The resonant frequency shall be determined for operation of minus 54°C in accordance with 4.5.3.1.

4.5.5.2 Efficiency at Resonance -- The efficiency at resonance shall be determined for operation at minus 54°C in accordance with 4.5.3.2.

4.5.5.3 Voltage Step-Up at Resonance -- The voltage step-up at resonance shall be determined for operation at minus 54°C in accordance with 4.5.3.3.

4.5.6 Resistance to Soldering Heat -- PET's shall be tested in accordance with method 210A of MIL-STD-202. The following details shall apply (see 3.4).

a. Depth of immersion of terminals in the molten solder - to a point 3/64 inch from the nearest insulating material.

b. Test condition - 240 ± 5°C for 5 ± 1 seconds.

c. Measurements after test - resonant frequency, efficiency at resonance and voltage step-up at resonance shall be tested in accordance with 4.5.3.1, 4.5.3.2 and 4.5.3.3.

4.5.7 Terminal Strength -- PET shall be tested for terminal secureness in accordance with method 211A of MIL-STD-202. The following details and exceptions shall apply:

a. Test condition letter - A.

b. Applied force - terminal secureness shall be tested by gradually applying a force of 1/2 pound to each pin terminal in the direction of the axis of the terminal (see 3.6).

4.5.8 Induced Voltage -- A test voltage sufficient to cause 150 percent of the rated input voltage shall be applied to the primary of the PET's. The test potential shall be applied for 5 ± 1/2 second. The load on the secondary shall be as specified in Figure 1. During the test, PET's shall be examined for evidence of continuous arcing, breakdown, and abrupt changes in input current (see 3.7).

4.5.9 Solderability -- PET's shall be tested in accordance with method 208C of MIL-STD-202. Each of the terminals is to be tested. Terminals shall be immersed to within 3/64 inch from the nearest insulating material (see 3.5).

4.5.10 Life -- PET's shall be tested in accordance with Method 108A of MIL-STD-202. The following details shall apply:

a. Distance of temperature measurements from specimens - two inches.

b. Still air requirement, not applicable.

c. Method of mounting and distance between specimens - mounted to electrical connections; distance between specimens two inches.

d. Test temperature and tolerance, 52°C ± 2°C.

e. Operating conditions - loading equal to 10 pf, 10 megohm and excitation of the primary equal to or greater than 1.25 times rated voltage. The electrical test circuit shall monitor the PET's during test for evidence of arcing, breakdown or abrupt changes in input current.

f. Test condition letter - C.

g. Measurements - Periodic measurements for voltage step-up at resonant frequency shall be made at intervals of 96 and 240 hours. The final measurements shall be made at the end of the 500 hour life period. After completion of life test, PET's shall be tested for induced voltage (4.5.8), resonant frequency (4.5.3.1), efficiency at resonance (4.5.3.2), input capacitance and dissipation factor (4.5.3.4). Samples shall also be examined for evidence of visual and mechanical damage (see 3.14).

4.5.11 Mechanical Vibration -- The operating potential shall not be applied to the assembly during vibration testing. Tolerance on specified frequencies shall be ± 2 Hz and tolerance on specified acceleration fields shall be ± 0.2 g. Mount the assemblies rigidly, singly or in groups. Subject the assembly to simple harmonic motion applied in a plane parallel to the radial axis at a varying frequency of 10 to 55 Hz. Vary the frequency from 10 to 55 Hz and return to 10 Hz in one minute while maintaining a constant 2.5 g's. Repeat this frequency sweep (two times total). At the conclusion of the two frequency sweeps, apply the simple harmonic motion to the PET in a plane perpendicular to the radial axis and repeat the above two frequency sweeps.

After the vibration tests, the PET shall be tested for resonant frequency (4.5.3.1), efficiency at resonance (4.5.3.2) and voltage step-up at resonance (4.5.3.3) (see 3.13).

4.5.12 Mechanical Shock -- The PET shall be rigidly mounted during shock testing. After the shock tests outlined below, the PET shall be tested for resonant frequency (4.5.3.1), efficiency at resonance (4.5.3.2) and voltage step-up at resonance (4.5.3.3).

4.5.12.1 Longitudinal Impulse -- Rigidly mount the PET with its radial axis in a vertical plane and subject the transformer to three pulses of nominal half sine wave shape having a peak amplitude of not less than 310 g's and duration 0.10 ± 0.05 millisecond. Impact oscillations as measured by the monitoring accelerometer shall be less than 30 g's, 12 milliseconds after initial pulse. Reverse the PET so that the pulse is still parallel to the radial axis but in the opposite direction, and subject it to three pulses of nominal half sine wave shape having a peak amplitude of not less than 310 g's and duration of 0.10 ± 0.05 millisecond. Impact oscillations as measured by the monitoring accelerometer shall be less than 30 g's, 12 milliseconds after initial pulse (see 3.12).

4.5.12.2 Transverse Impulse -- Rigidly mount the PET with its radial axis in a horizontal (transverse) plane and subject the assembly to 3 pulses of nominal half sine wave shape whose peak amplitude is 910 ± 45 g's, and whose duration of 0.10 ± 0.05 millisecond. After-oscillations must not exceed 90 g's at 12 milliseconds after initial pulse (see 3.12).

4.5.13 Thermal Shock -- PET's shall be tested by exposing them alternately for 15 minutes minimum to +68°C and to -57°C with a minimum of 1 minute between temperature extremes. This sequence will be repeated 5 times (see 3.9).

4.5.14 High Temperature Storage -- PET's shall be subjected to a minimum storage period of 8 hours at plus 71°C. The ambient temperature shall then be gradually lowered to plus 52°C. Measurements shall then be made of the resonant frequency, efficiency at resonance and voltage step-up ratio in accordance with 4.5.4.1, 4.5.4.2 and 4.5.4.3 (see 3.10).

4.5.15 Low Temperature Storage -- PET's shall be subjected to a minimum storage period of 2 hours at minus 65°C. The ambient temperature shall then be gradually raised to minus 54°C. Measurements shall then be made of the resonant frequency, efficiency at resonance and voltage step-up ratio in accordance with 4.5.5.1, 4.5.5.2 and 4.5.5.3 (see 3.11).

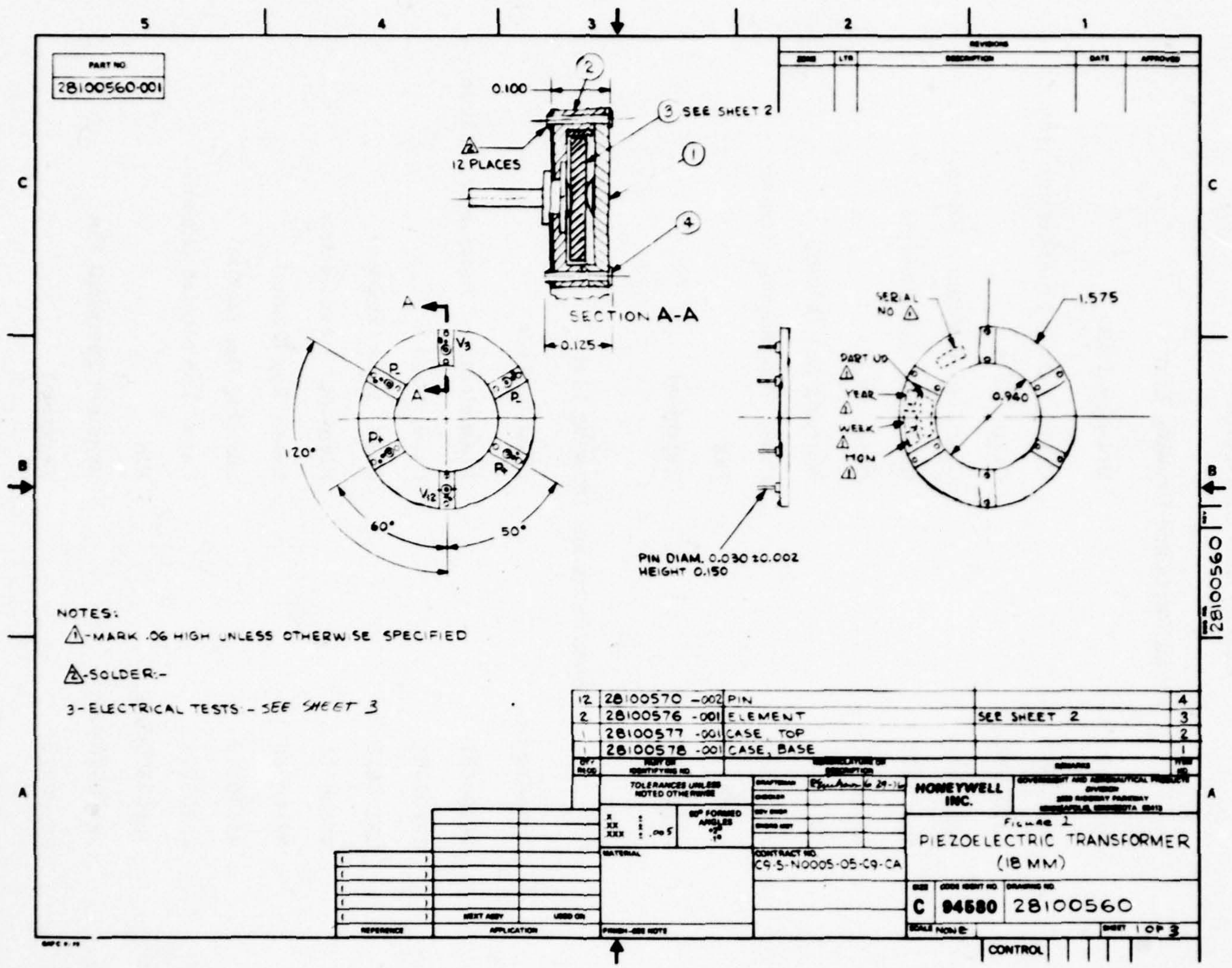
APPENDIX B
PARTS AND DRAWINGS

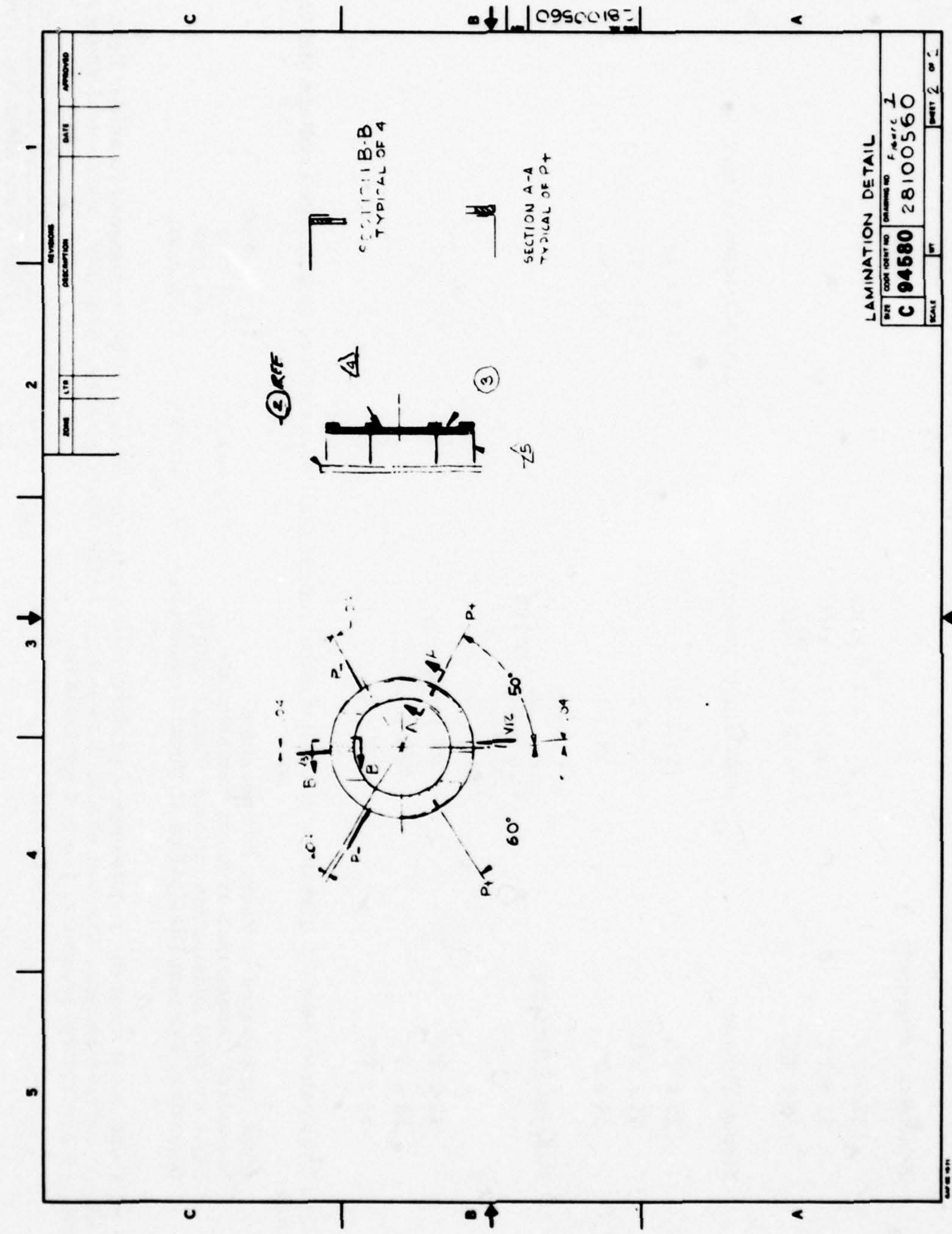
18mm Parts and Drawing List

Drawing No.	Drawing Title
28100560	Piezoelectric Transformer (18mm)
28100578	Case, Base
28100581	Case, Base Molding (18mm)
28100576	Element, Piezoelectric
28100577	Case, Top
28100579	Shorting Bar (18mm)
28100580	Case, Top Molding (18mm)
28100570-002	Pin
28100572	Terminal

25mm Parts and Drawing List

Drawing No.	Drawing Title
28100561	Piezoelectric Transformer (25mm)
28100568	Case, Base
28100575	Case, Base (Molded)
28100571	Element, Piezoelectric
28100569	Case, Top (25mm)
28100573	Shorting Bar (25mm)
28100574	Case, Top Molded (25mm)
28100570-001	Pin
28100570-003	Negative Terminal Pin
28100572	Terminal


PART NO
28100560-001
0.100
SEE SHEET 2
12 PLACES
SECTION A-A
0.125
A
V3
V12
P-
P+
120°
60°
50°
SERIAL NO
PART NO
YEAR
WEEK
MON
1.575
0.940
PIN DIAM. 0.030 ±0.002
HEIGHT 0.150
NOTES:
1-MARK .06 HIGH UNLESS OTHERWISE SPECIFIED
2-SOLDER:-
3-ELECTRICAL TESTS - SEE SHEET 3
12 28100570 -002 PIN 4
2 28100576 -001 ELEMENT SEE SHEET 2 3
1 28100577 -001 CASE, TOP 2
1 28100578 -001 CASE, BASE 1
TOLERANCES UNLESS NOTED OTHERWISE
CONTRACT NO
C9-S-N0005-05-C9-CA
HONEYWELL INC.
Figure 1
PIEZOELECTRIC TRANSFORMER
(18 MM)
C 94580 28100560
SCALE NONE
SHEET 1 OF 3
CONTROL


LAMINATION DETAIL
SIZE C
CODE IDENT NO 94580
DRAWING NO 28100560
Figure 1
SCALE
SHEET 2
SECTION B-B
TYPICAL OF 4
SECTION A-A
TYPICAL OF P+
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
60°
50°
28100560

ELECTRICAL REQUIREMENTS

When a 5 volt (p-p) sine wave input voltage to the PET is applied in parallel to the primary terminals (P_+ and P_-) and the ceramic is driven at its primary resonant frequency with the electrical load on the V_{12} secondary terminal of 2 megohms and 8 pf, and V_3 terminal of 100 megohms and 3 pf, the packaged units shall meet the following electrical requirements.

Resonant Frequency:

22 ± 2°C	32.3 ± 1.6 kHz
52 ± 2°C	32.5 ± 1.6 kHz
-54 ± 2°C	31.6 ± 1.6 kHz

Stepup Voltage	V_{12} output/input voltage	V_3 output/input voltage
22 ± 2°C	107 ± 27	173 ± 43
52 ± 2°C	107 ± 27	173 ± 43
-54 ± 2°C	58 ± 14	90 ± 18

Percent Efficiency

$$\frac{\dfrac{V_{12}^2}{R_{12}} + \dfrac{V_3^2}{R_3}}{V_{in} \quad I_{in}} \times 100$$

22 ± 2°C	30% min.
52 ± 2°C	30% min.
-54 ± 2°C	15% min.

Capacitance and Dissipation Factor: The input and output capacitance shall be measured at a nominal voltage and drive of 1 volt and 1 kHz.

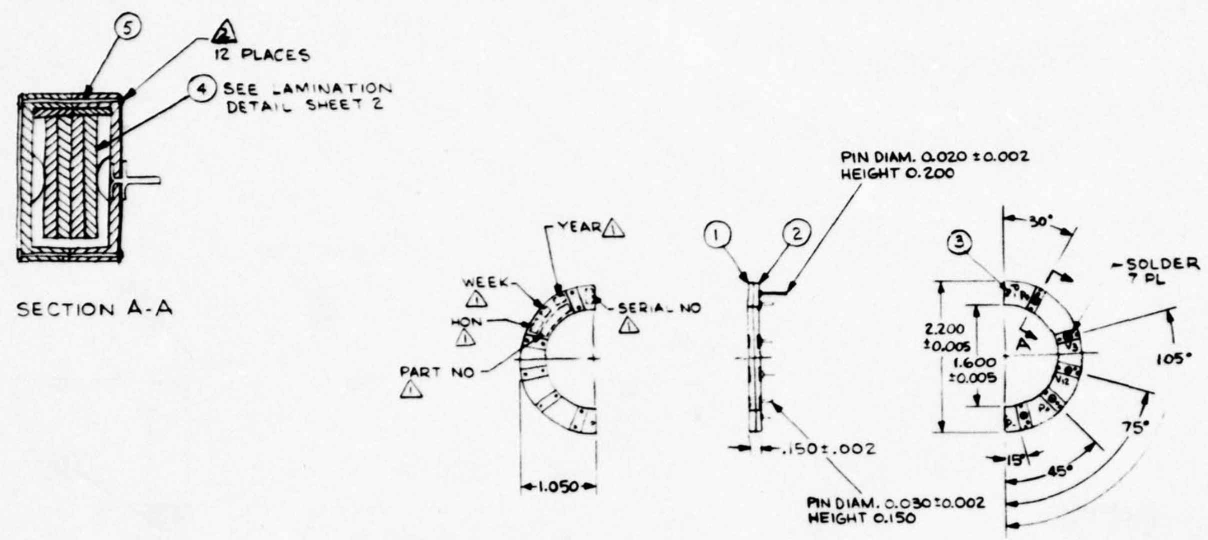
Input Capacitance at Room Temperature		14 ± 1.4 nf
Secondary Capacitance at Room Temperature	V_{12} and V_3	10 pf max.
Input Percent Dissipation at Room Temperature		1.5% max.
Secondary Percent Dissipation at Room Temperature	V_{12} and V_3	1.5% max.

The package PET unit must meet the requirements as described herein for solderability, resistance to solder heat, terminal strength, induced voltage, thermal shock, high and low temperature storage, humidity, mechanical shock and vibration, reduced barometric pressure, life and workmanship.

Electrical Requirements

Size	Code Ident No.	Drawing No.
C	94580	28100560
		Sheet 3 of 3

PART NO.
28100561-001



NOTES:

1- MARK .06 HIGH UNLESS OTHERWISE SPECIFIED

2- SOLDER.

3-ELECTRICAL TESTS - SEE SHEET 3

4- BOND WITH EPOXY .003 TO .004 THICK

5- GOLD LEAD WIRE .005 BY .010

QTY REQD	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	REMARKS	ITEM NO
12	281100570-001	PIN		5
4	281100571-001	ELEMENT	SEE SHEET 2	4
1	28100570-003	PIN	(P-)	3
1	28100574-001	CASE, TOP		2
1	28100575-001	CASE, BASE		1

TOLERANCES UNLESS NOTED OTHERWISE
.X ±
.XX ±
.XXX ±
90° FORMED ANGLES ±2° ±1°

MATERIAL

FINISH—SEE NOTE

DRAFTSMAN | CHECKER | DEV ENGR | ENGRG MGT

CONTRACT NO

REFERENCE | NEXT ASSY | USED ON | APPLICATION

HONEYWELL INC.

GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
2600 RIDGWAY PARKWAY
MINNEAPOLIS, MINNESOTA 55413

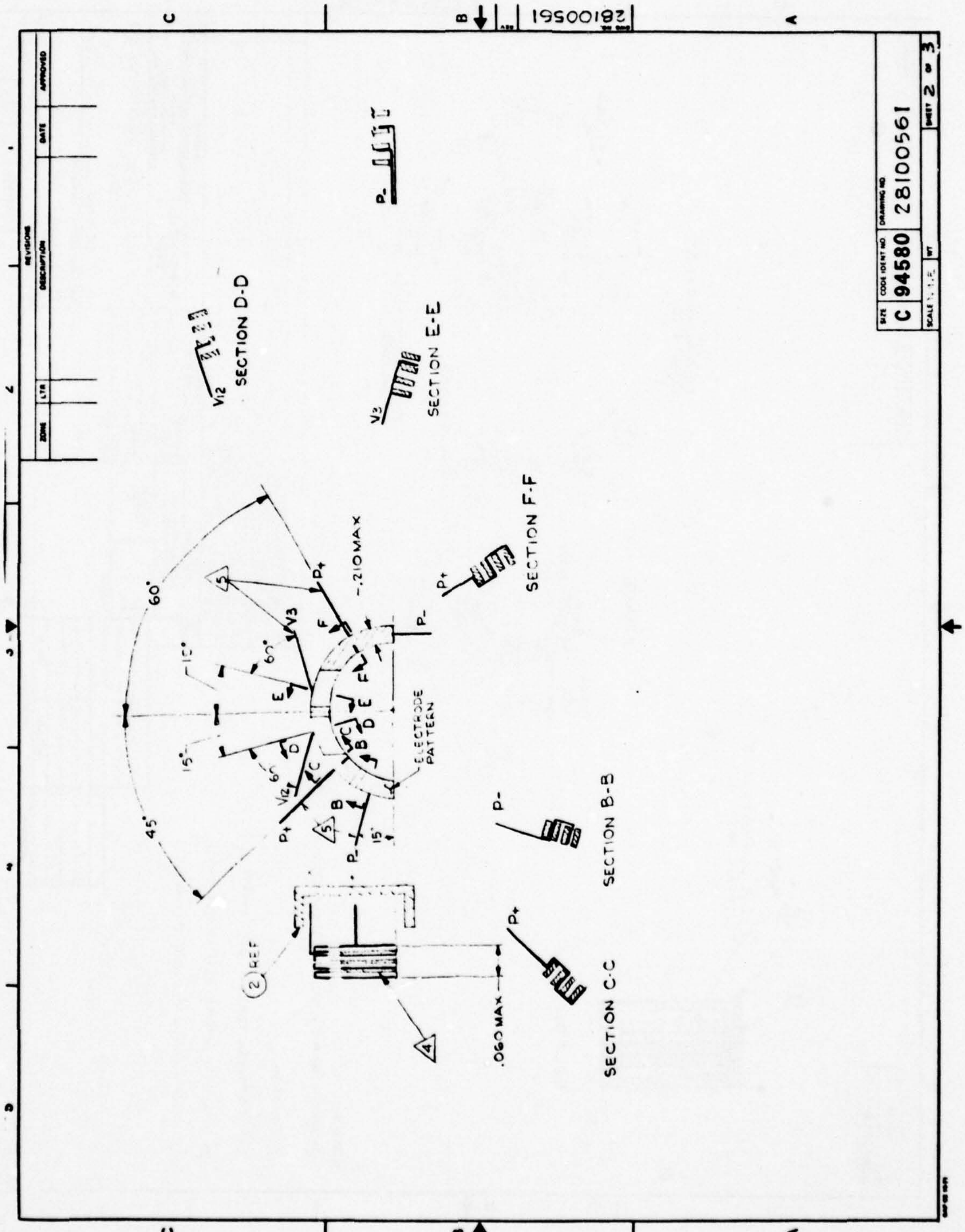
PIEZOELECTRIC TRANSFORMER (25MM)

Figure 2

SIZE	CODE IDENT NO	DRAWING NO
C	94580	28100561

SCALE NONE | SHEET 1 OF 3

CONTROL


SECTION C-C
.060 MAX
REF
SECTION B-B
ELECTRODE PATTERN
45°
60°
15°
60°
-.210 MAX
SECTION F-F
SECTION D-D
SECTION E-E
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
SIZE C
CODE IDENT NO 94580
DRAWING NO 28100561
SHEET 2 OF 3
28100561

ELECTRICAL REQUIREMENTS

When a 5 volt (p-p) sine wave input voltage to the PET is applied in parallel to the primary **terminals** (P_+ and P_-), and the ceramic is driven at its primary resonant frequency with an electrical load on each secondary terminal (V_{12} and V_3) of 10 megohms and 10 pf, the packaged units shall meet the following electrical requirements.

Resonant Frequency:

22 ± 2°C	33.9 ± 0.2 kHz
52 ± 2°C	34.1 ± 0.2 kHz
-54 ± 2°C	33.3 ± 0.2 kHz

Step-up Voltage Ratio V_{12} or V_3 output/input voltage

22 ± 2°C	170 ± 10%
52 ± 2°C	170 ± 10%
-54 ± 2°C	85 ± 10%

Percent Efficiency $\dfrac{V_{12}^2 + V_3^2 \times 100}{(V_{in.})(I_{in.})(10 \times 10^6)}$

22 ± 2°C	45 min.
52 ± 2°C	50 min.
-54 ± 2°C	25 min.

Capacitance and Dissipation Factor: The input and output capacitance shall be measured at a nominal voltage and drive of 1 volt and 1 kHz.

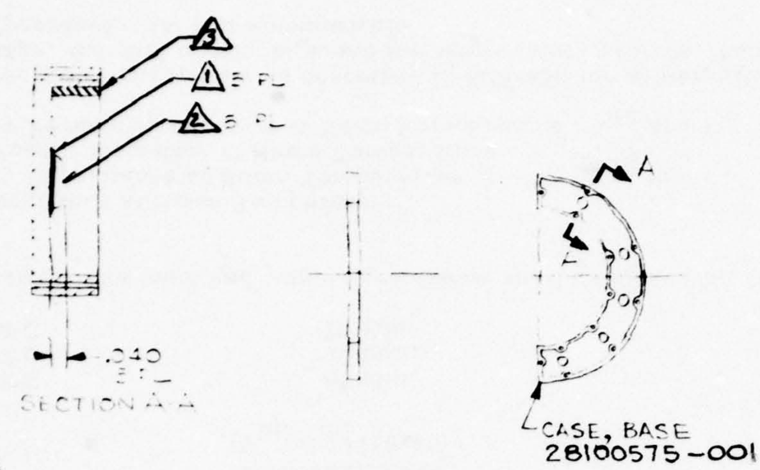
Input Capacitance at Room Temperature		14,000 pf ± 4%
Secondary Capacitance at Room Temperature	V_{12} and V_3	7.6 pf ± 4%
Input Percent Dissipation at Room Temperature		1.75% max.
Secondary Percent Dissipation at Room Temperature	V_{12} and V_3	4.6% max.

The package PET unit must meet the requirements as described in SCS-480 for solderability, resistance to solder heat, terminal strength, induced voltage, thermal shock, high and low temperature storage, humidity, mechanical shock and vibration, reduced barometric pressure, life and workmanship.

Electrical Requirements

Size	Code Ident No.	Drawing No.
C	94580	28100561
		Sheet 3 of 3

PART NO.
28100568-001



NOTES:
1 - SILASTIC PRIMER
2 - SILASTIC PAD
3 - TRANSFER TAPE

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

28100568

1	28100575	CASE BASE (MOLDED)	25mm	1

NEXT ASSY	USED ON
28100568	PZT TRANS

APPLICATION

TOLERANCES UNLESS NOTED OTHERWISE
.X ±
.XX ±
.XXX ±
90° FORMED ANGLES ±2° ±1°
MATERIAL
FINISH—SEE NOTE

DRAFTSMAN
CHECKER
DEV ENGR
ENGRG MGT
CONTRACT NO

HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
2600 RIDGWAY PARKWAY
MINNEAPOLIS, MINNESOTA 55413

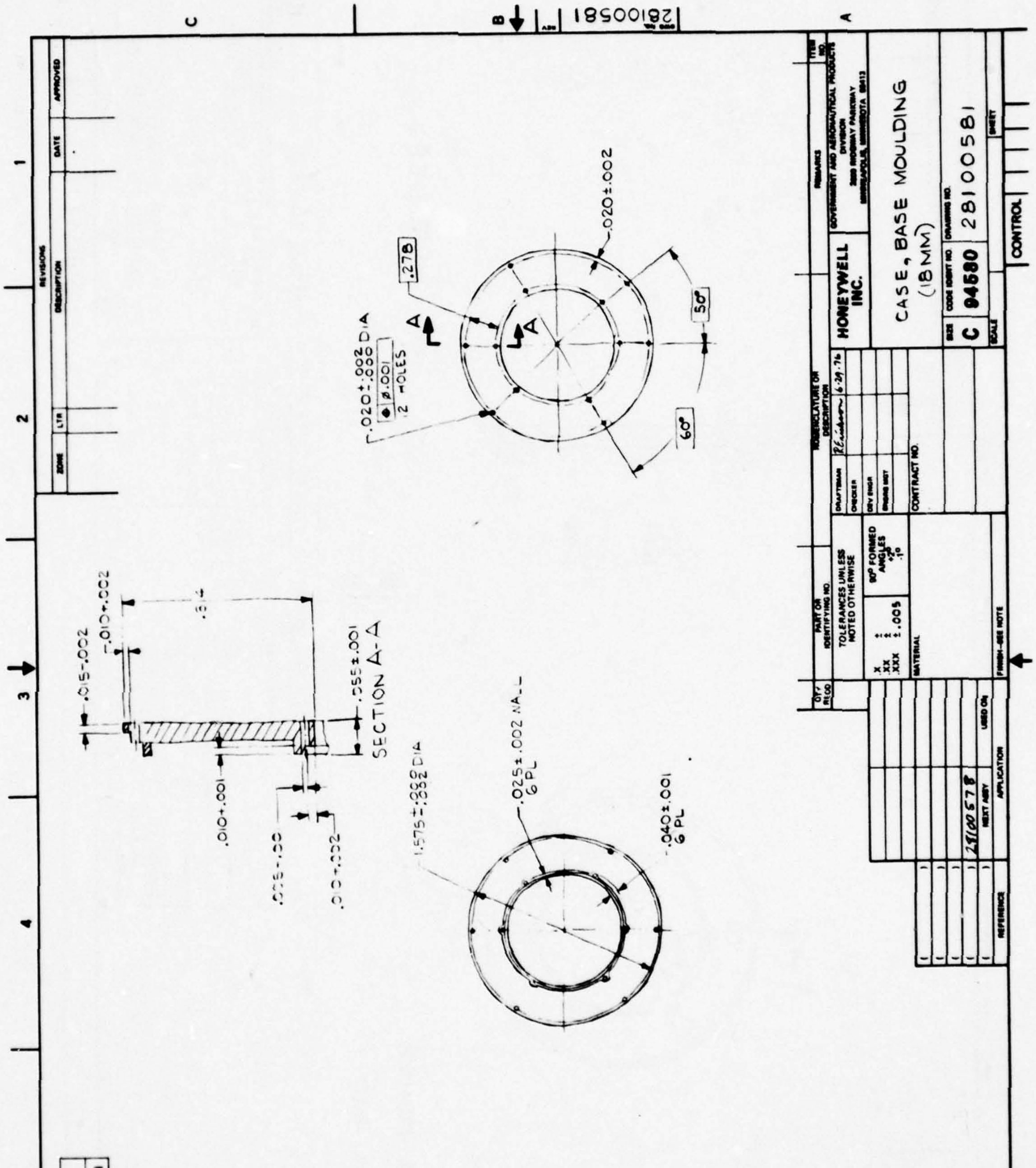
CASE, BASE

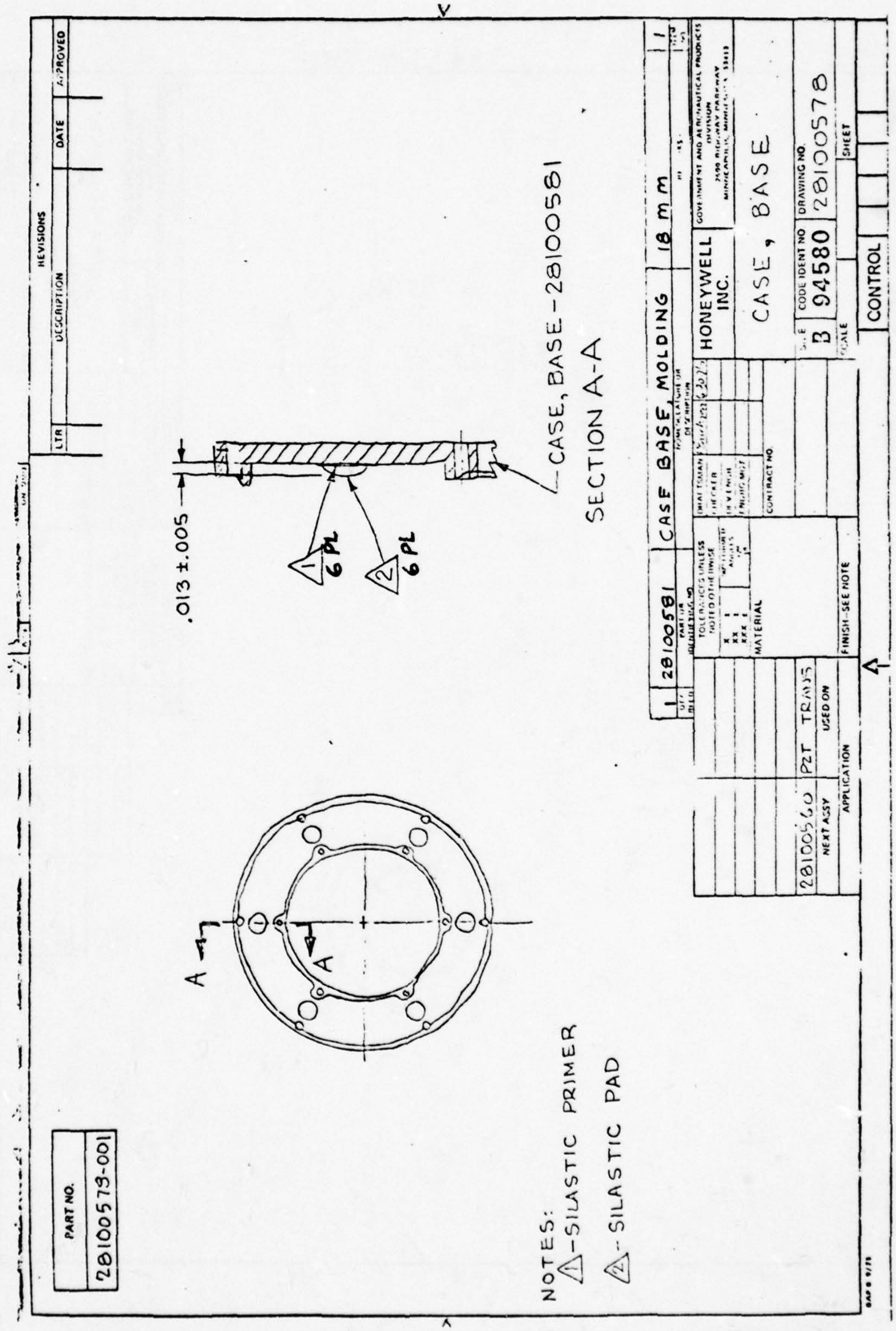
SIZE	CODE IDENT NO.	DRAWING NO.
B	94580	28100568

SCALE NONE SHEET

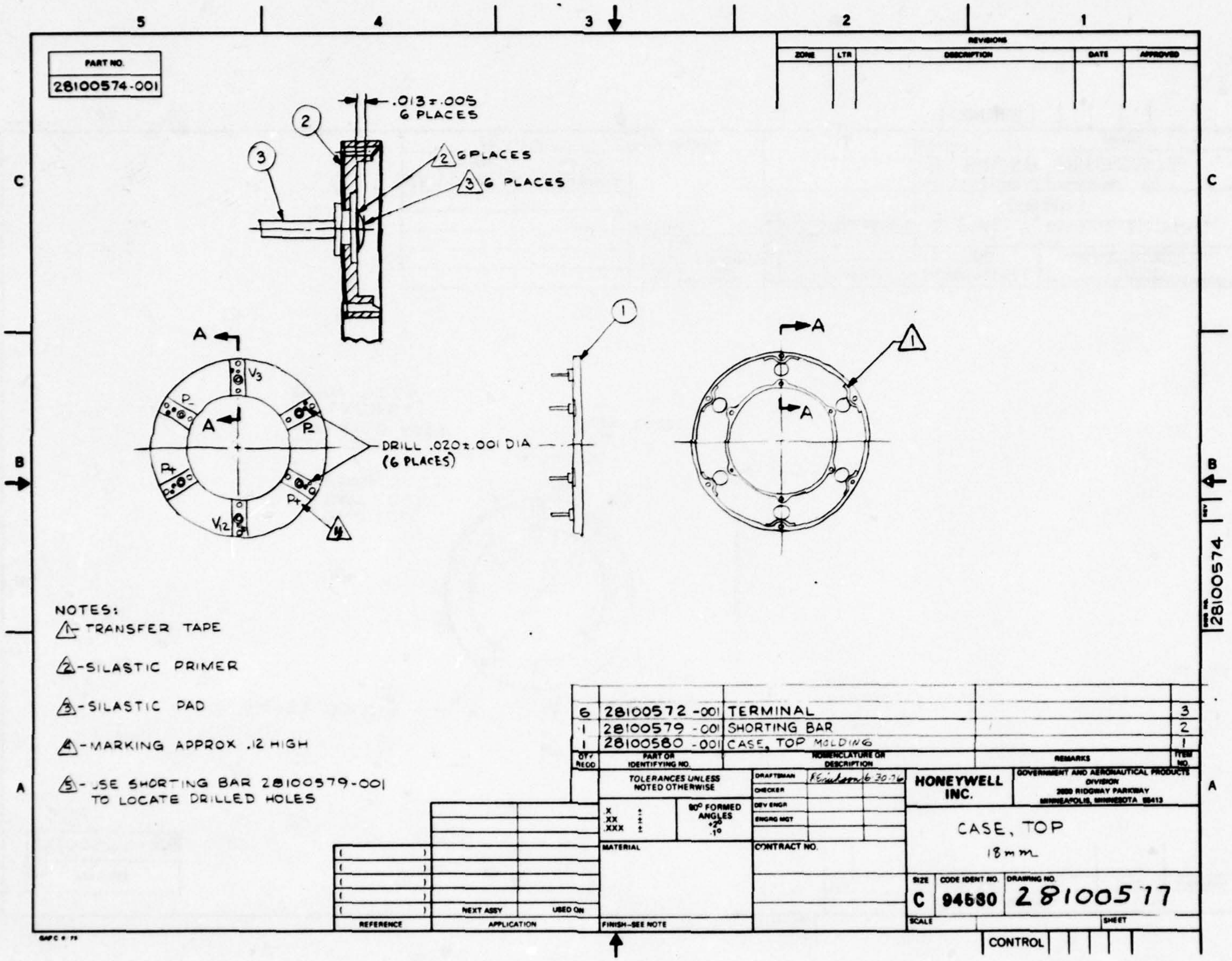
CONTROL

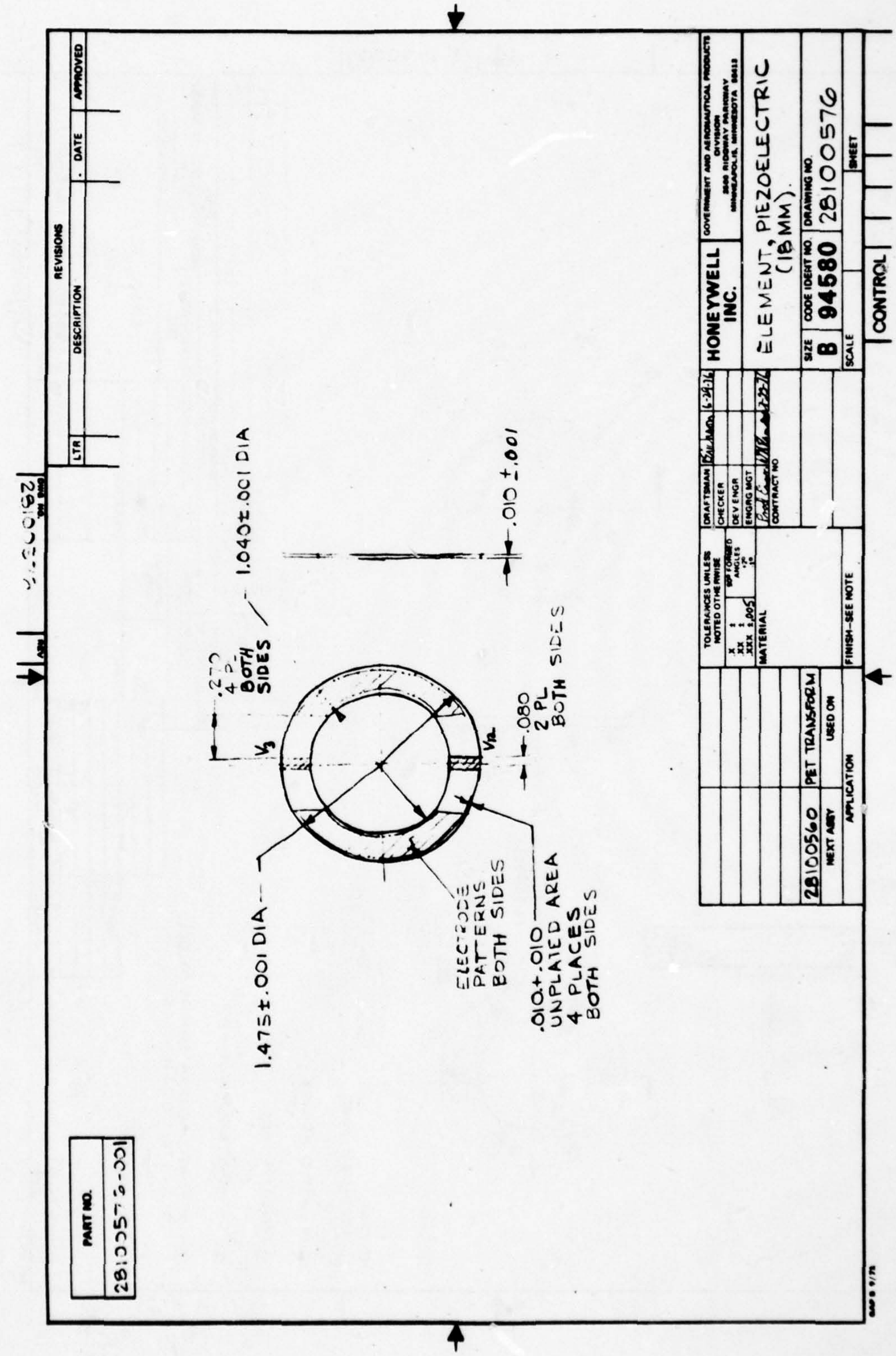
GAP 9 9/75


HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
CASE, BASE MOULDING
(18MM)
C
94580
28100581
CONTROL
PART NO
28100581-001
SECTION A-A
TOLERANCES UNLESS NOTED OTHERWISE
.020±.002
12 HOLES
.278
50°
60°
.040±.001
6 PL
REVISIONS
CONTRACT NO.
MATERIAL
NEXT ASSY
APPLICATION
USED ON
REFERENCE

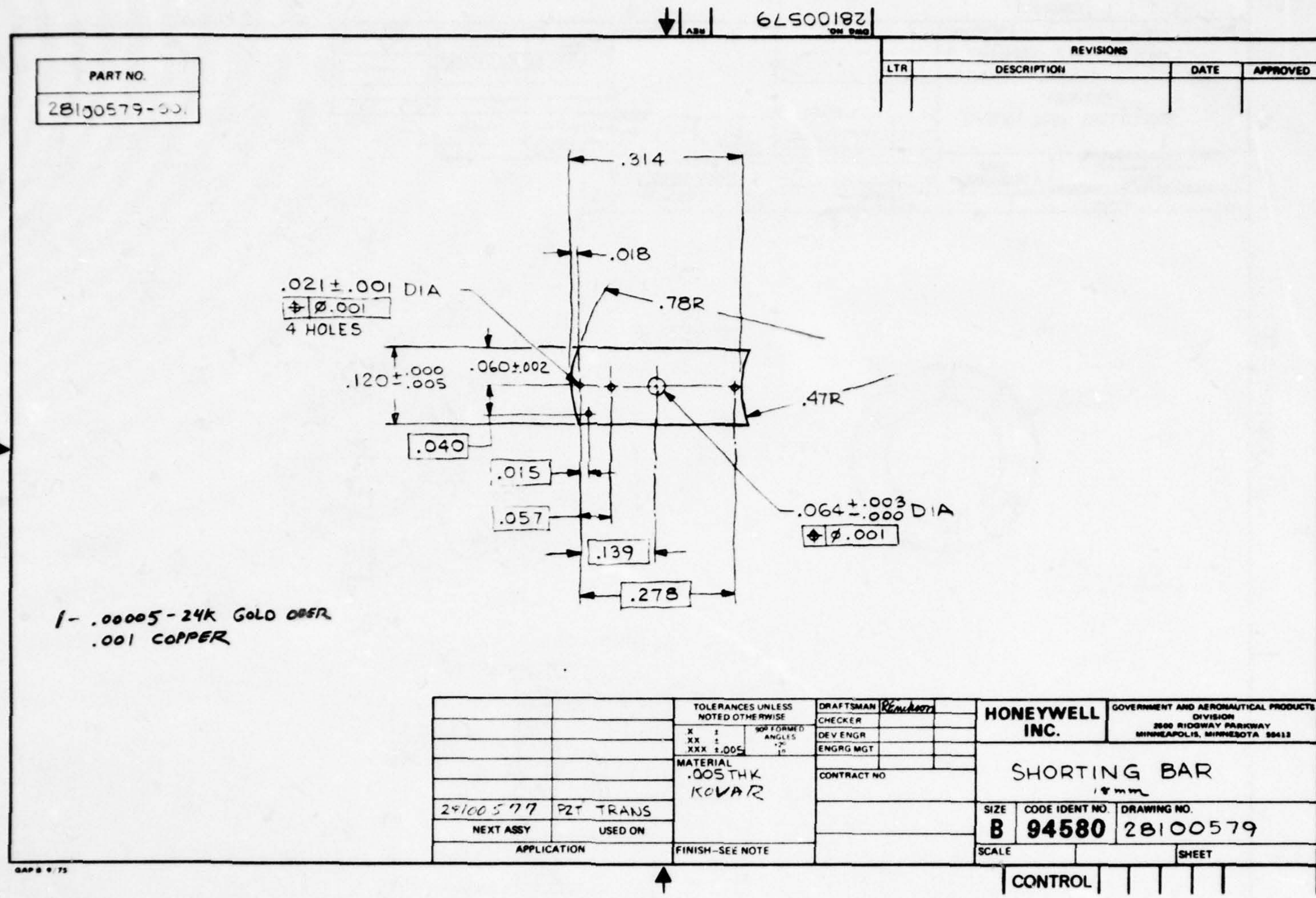


REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
PART NO.
28100578-001
NOTES:
1 -SILASTIC PRIMER
2 -SILASTIC PAD
A
A
.013 ±.005
1 6 PL
2 6 PL
CASE, BASE-28100581
SECTION A-A
28100581
CASE BASE, MOLDING
18 mm
HONEYWELL INC.
CASE, BASE
B
94580
28100578
CODE IDENT NO
DRAWING NO.
SCALE
SHEET
CONTROL
TOLERANCES UNLESS NOTED OTHERWISE
MATERIAL
FINISH-SEE NOTE
DRAFTSMAN
CHECKER
CONTRACT NO
28100560
NEXT ASSY
PZT TRANS
USED ON
APPLICATION

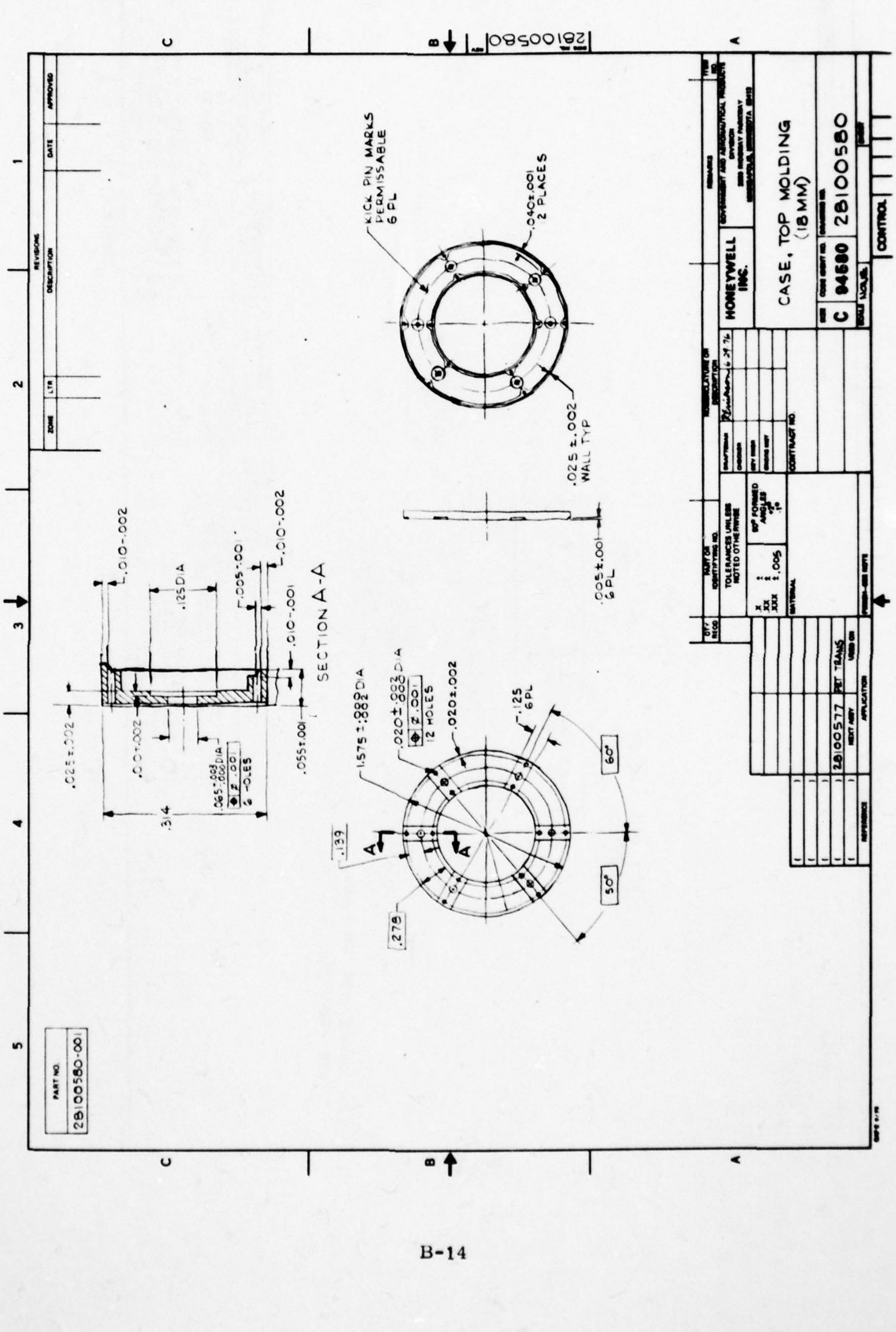

PART NO.
28100574-001
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
.013±.005
6 PLACES
2 6 PLACES
3 6 PLACES
DRILL .020±.001 DIA
(6 PLACES)
V3
P-
P+
V12
NOTES:
1 - TRANSFER TAPE
2 - SILASTIC PRIMER
3 - SILASTIC PAD
4 - MARKING APPROX .12 HIGH
5 - USE SHORTING BAR 28100579-001 TO LOCATE DRILLED HOLES
6 28100572 -001 TERMINAL 3
1 28100579 -001 SHORTING BAR 2
1 28100580 -001 CASE, TOP MOLDING 1
QTY REQD
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
REMARKS
ITEM NO.
TOLERANCES UNLESS NOTED OTHERWISE
90° FORMED ANGLES
MATERIAL
FINISH—SEE NOTE
DRAFTSMAN
CHECKER
DEV ENGR
ENGRG MGT
CONTRACT NO.
HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
2600 RIDGWAY PARKWAY
MINNEAPOLIS, MINNESOTA 55413
CASE, TOP
18 mm
SIZE
C
CODE IDENT NO
94580
DRAWING NO
28100577
SCALE
SHEET
CONTROL
REFERENCE
NEXT ASSY
USED ON
APPLICATION
28100574



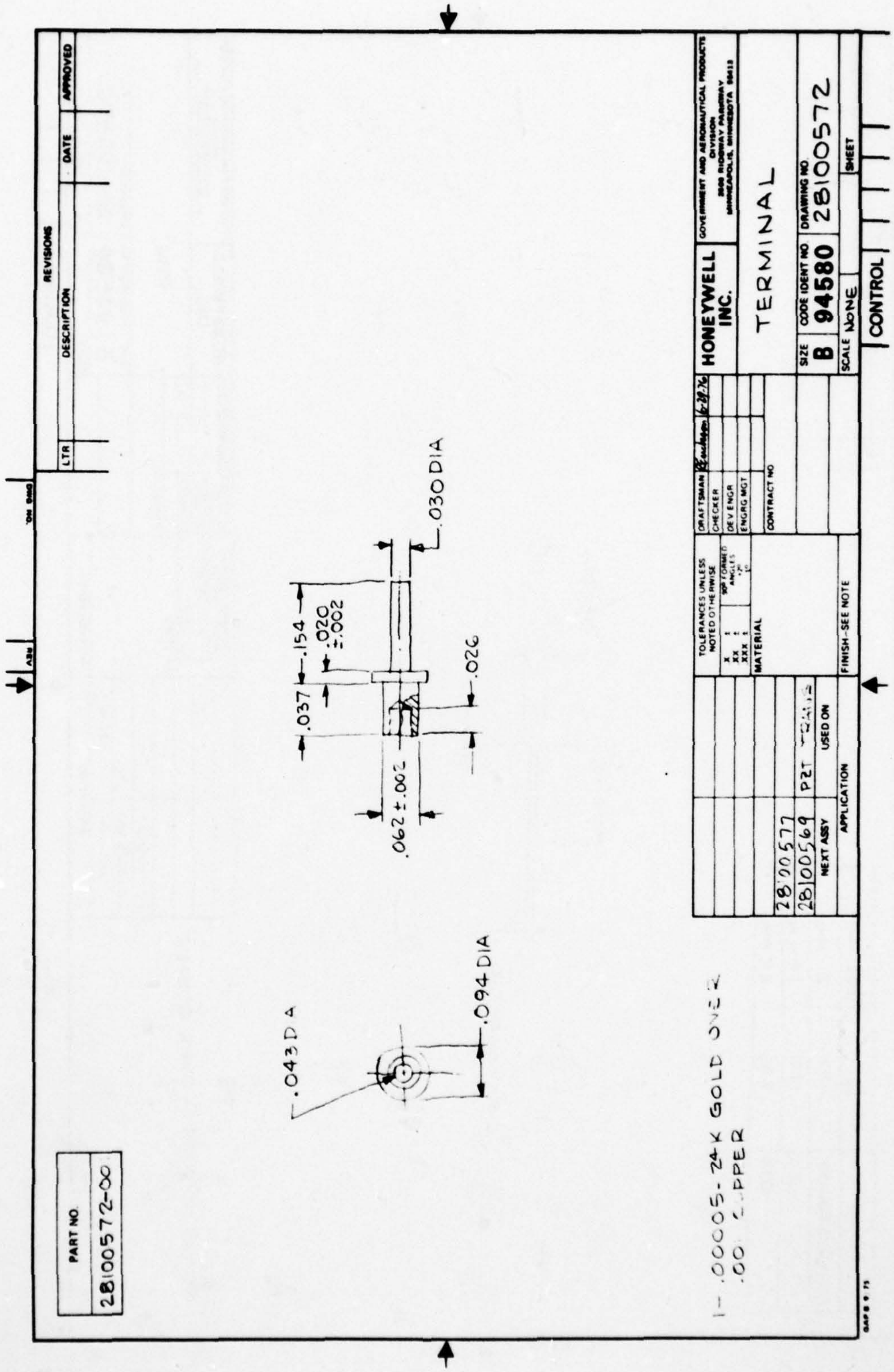
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
1.040±.001 DIA
.010±.001
.270
4 PL
BOTH SIDES
.080
2 PL
BOTH SIDES
1.475±.001 DIA
ELECTRODE PATTERNS BOTH SIDES
.010±.010
UNPLATED AREA
4 PLACES
BOTH SIDES
PART NO.
28100576-001
TOLERANCES UNLESS NOTED OTHERWISE
MATERIAL
FINISH-SEE NOTE
DRAFTSMAN
CHECKER
DEV ENGR
ENGRG MGT
CONTRACT NO
HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
ELEMENT, PIEZOELECTRIC (18MM)
SIZE
B
CODE IDENT NO.
94580
DRAWING NO.
28100576
SCALE
SHEET
CONTROL
28100560
PET TRANSFORM
NEXT ASSY
USED ON
APPLICATION



28100579
DWG NO.
REV
PART NO.
28100579-00
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
.314
.018
.021 ± .001 DIA
⌖ Ø.001
4 HOLES
.78R
.120 +.000 -.005
.060 ±.002
.47R
.040
.015
.057
.139
.278
.064 +.003 -.000 DIA
⌖ Ø.001
1 - .00005 - 24K GOLD OVER .001 COPPER
TOLERANCES UNLESS NOTED OTHERWISE
X ±
XX ±
XXX ±.005
90° FORMED ANGLES ±2° ±1°
MATERIAL
.005 THK KOVAR
DRAFTSMAN
CHECKER
DEV ENGR
ENGRG MGT
CONTRACT NO
HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
2600 RIDGWAY PARKWAY
MINNEAPOLIS, MINNESOTA 55413
SHORTING BAR
18mm
SIZE
B
CODE IDENT NO.
94580
DRAWING NO.
28100579
SCALE
SHEET
CONTROL
28100577
PZT TRANS
NEXT ASSY
USED ON
APPLICATION
FINISH-SEE NOTE

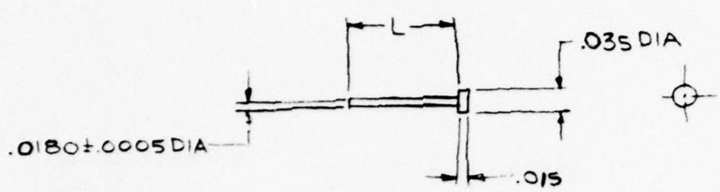


CASE, TOP MOLDING
(18MM)
HONEYWELL INC.
C 94580 28100580
28100580
PART NO. 28100580-001
SECTION A-A
KICK PIN MARKS PERMISSABLE 6 PL
.040±.001 2 PLACES
.025±.002 WALL TYP
.005±.001 6 PL
1.575±.882 DIA
.020±.002 DIA
12 HOLES
.020±.002
.125 6PL
60°
50°
.139
.278
.314
.125 DIA
.010-.002
.005-.001
.010-.001
.055±.001
.025±.002
28100577
PET TRANS
CONTROL



PART NO.
28100572-00
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
.043 DIA
.094 DIA
.062±.002
.037
.154
.020
±.002
.026
.030 DIA
1 - .00005 - 24K GOLD OVER
COPPER
28100577
28100569
PZT
NEXT ASSY
USED ON
APPLICATION
TOLERANCES UNLESS NOTED OTHERWISE
MATERIAL
FINISH-SEE NOTE
DRAFTSMAN
CHECKER
DEV ENGR
ENGRG MGT
CONTRACT NO
HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
TERMINAL
SIZE
B
CODE IDENT NO
94580
DRAWING NO
28100572
SCALE NONE
SHEET
CONTROL

PART NO.	L	USED ON
28100570-001	.170	25mm
-002	.120	18mm
-003	.285	25 mm



1-.00005-24K GOLD OVER COPPER

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

ASSY 28100570 ON DWG

NEXT ASSY	USED ON
28100561	
28100560	

APPLICATION

TOLERANCES UNLESS NOTED OTHERWISE
X ±
XX ±
XXX ±.005
90° FORMED ANGLES ±2°

MATERIAL

FINISH-SEE NOTE 1

DRAFTSMAN [signature] 6-29-76
CHECKER
DEV ENGR
ENGRG MGT

CONTRACT NO

HONEYWELL INC.

GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
2600 RIDGWAY PARKWAY
MINNEAPOLIS, MINNESOTA 55413

PIN

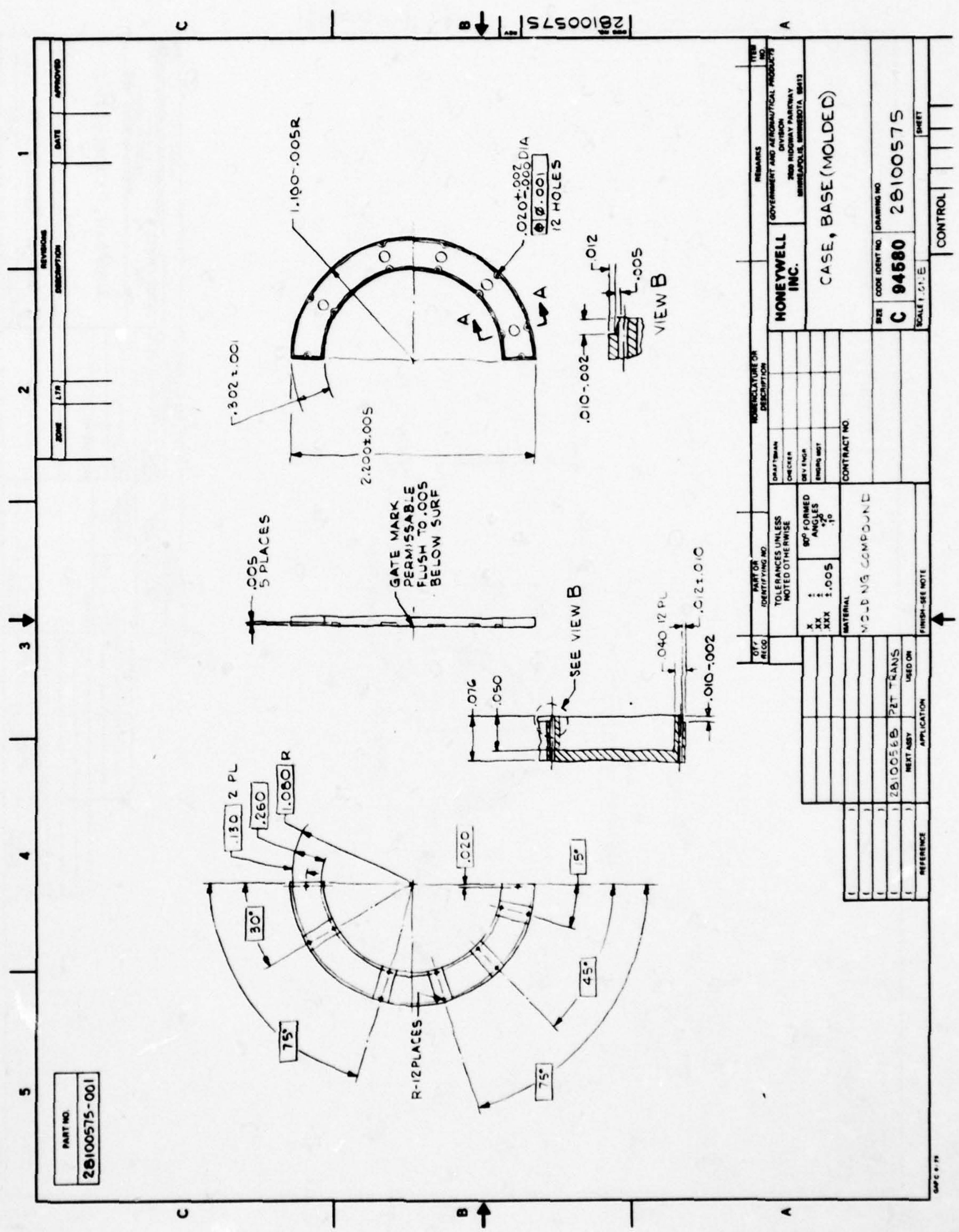
SIZE	CODE IDENT NO	DRAWING NO
B	94580	28100570

SCALE

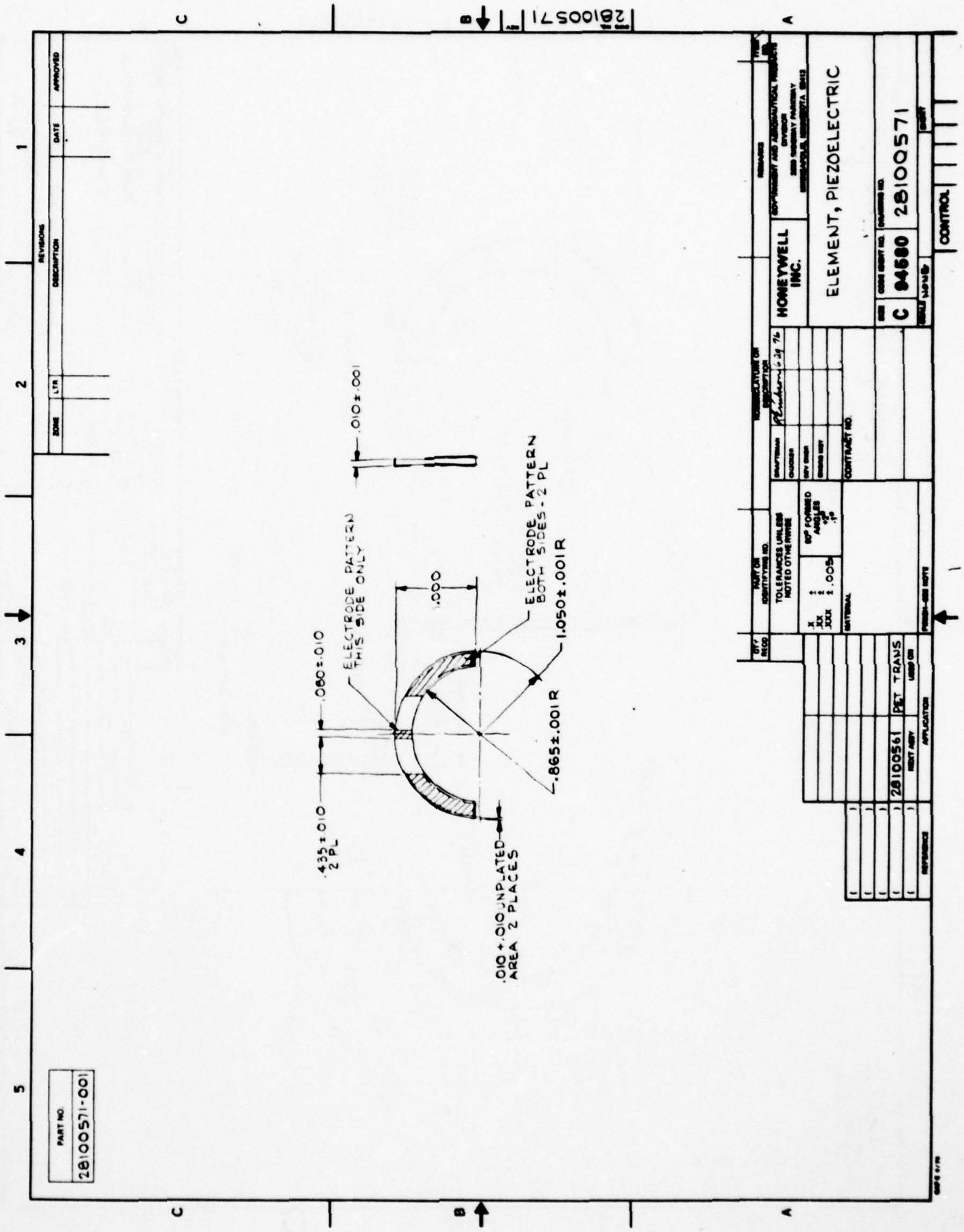
SHEET

CONTROL

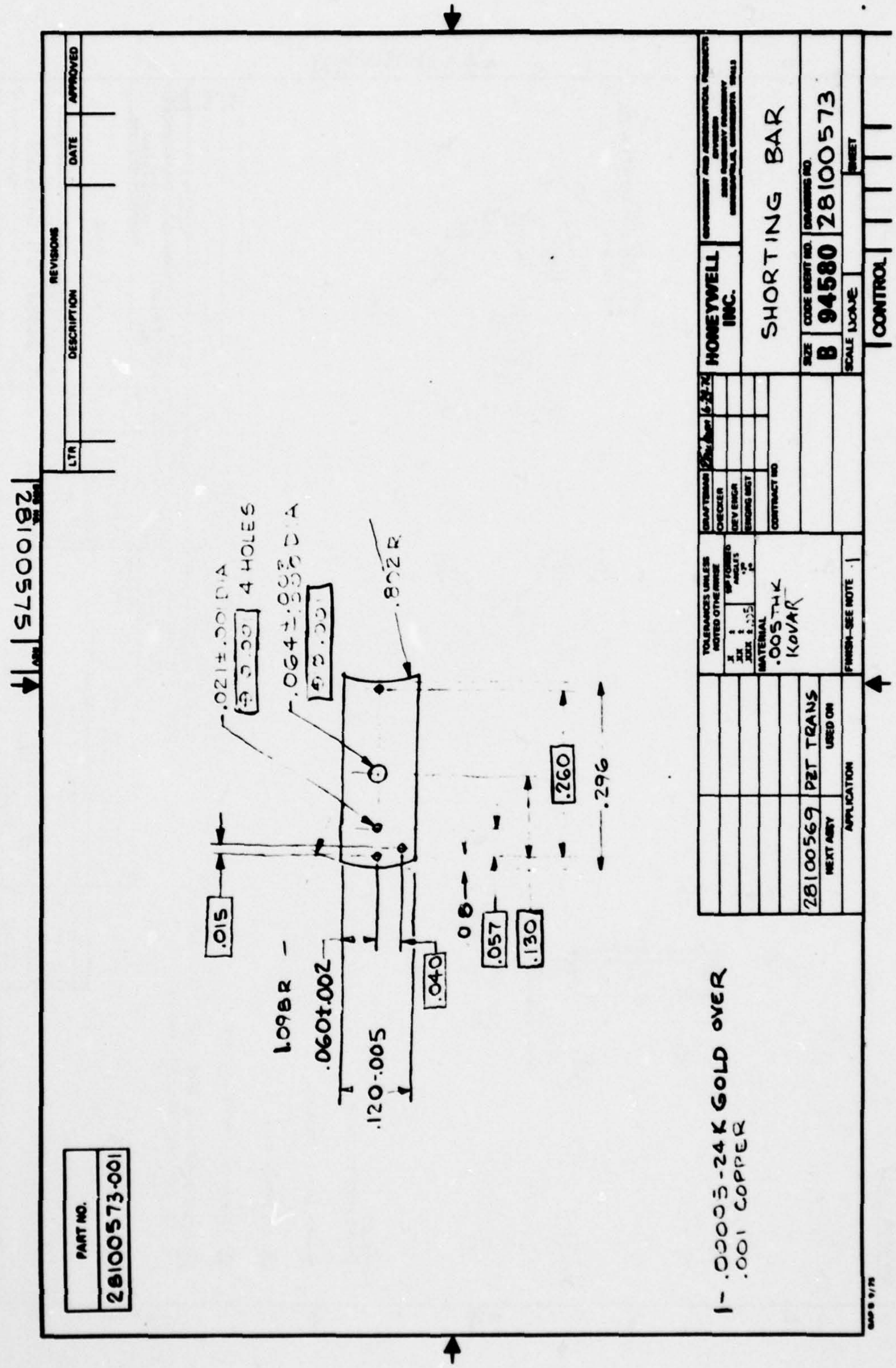
GAP 9/73



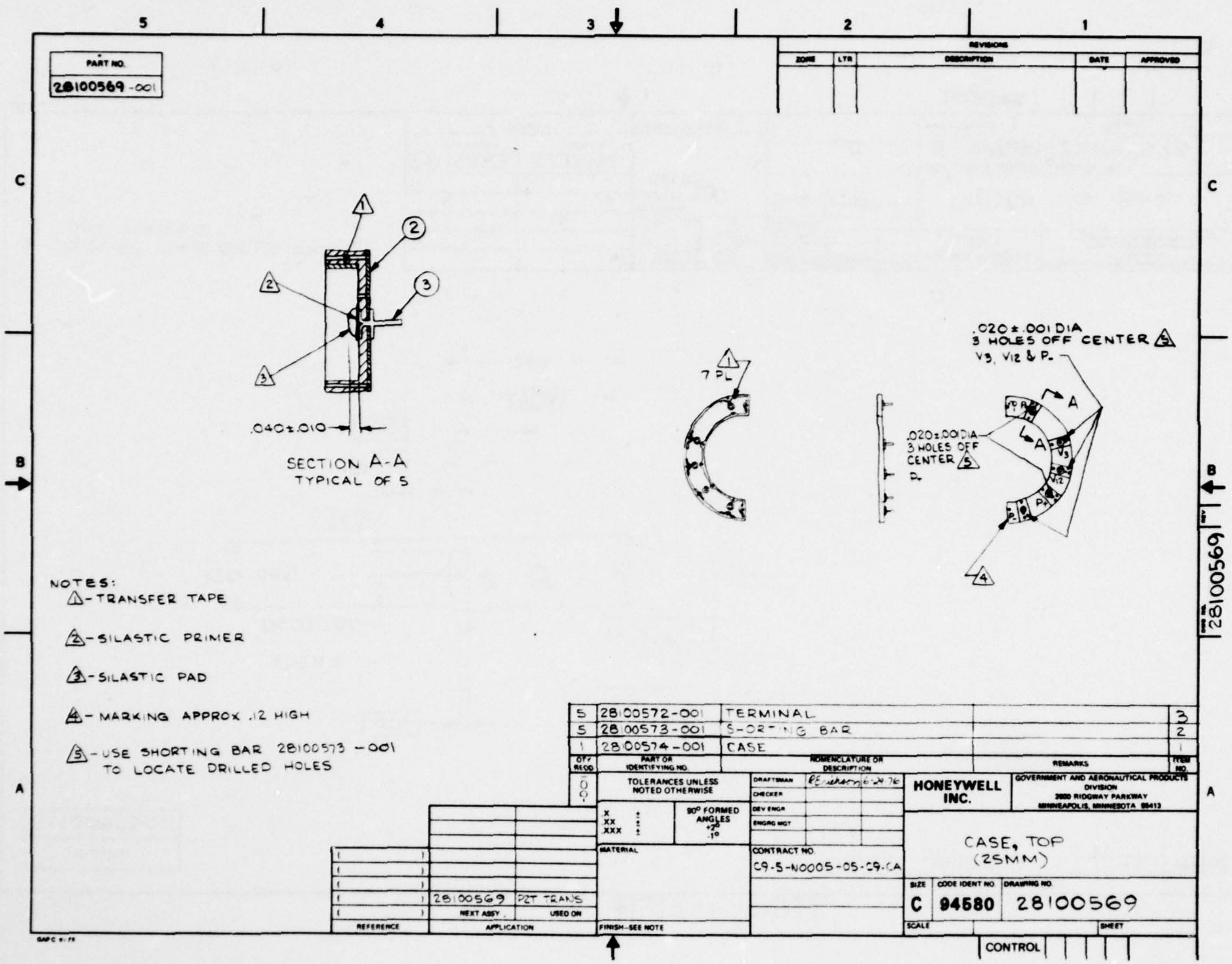
HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
CASE, BASE (MOLDED)
C
94580
28100575
CONTROL
PART NO.
28100575-001
TOLERANCES UNLESS NOTED OTHERWISE
MOLDING COMPOUND
28100568
NEXT ASSY
APPLICATION
REFERENCE
GATE MARK PERMISSABLE FLUSH TO .005 BELOW SURF
.005 5 PLACES
SEE VIEW B
VIEW B
12 HOLES
R-12 PLACES
1.100-.005R
2.200±.005
.302±.001

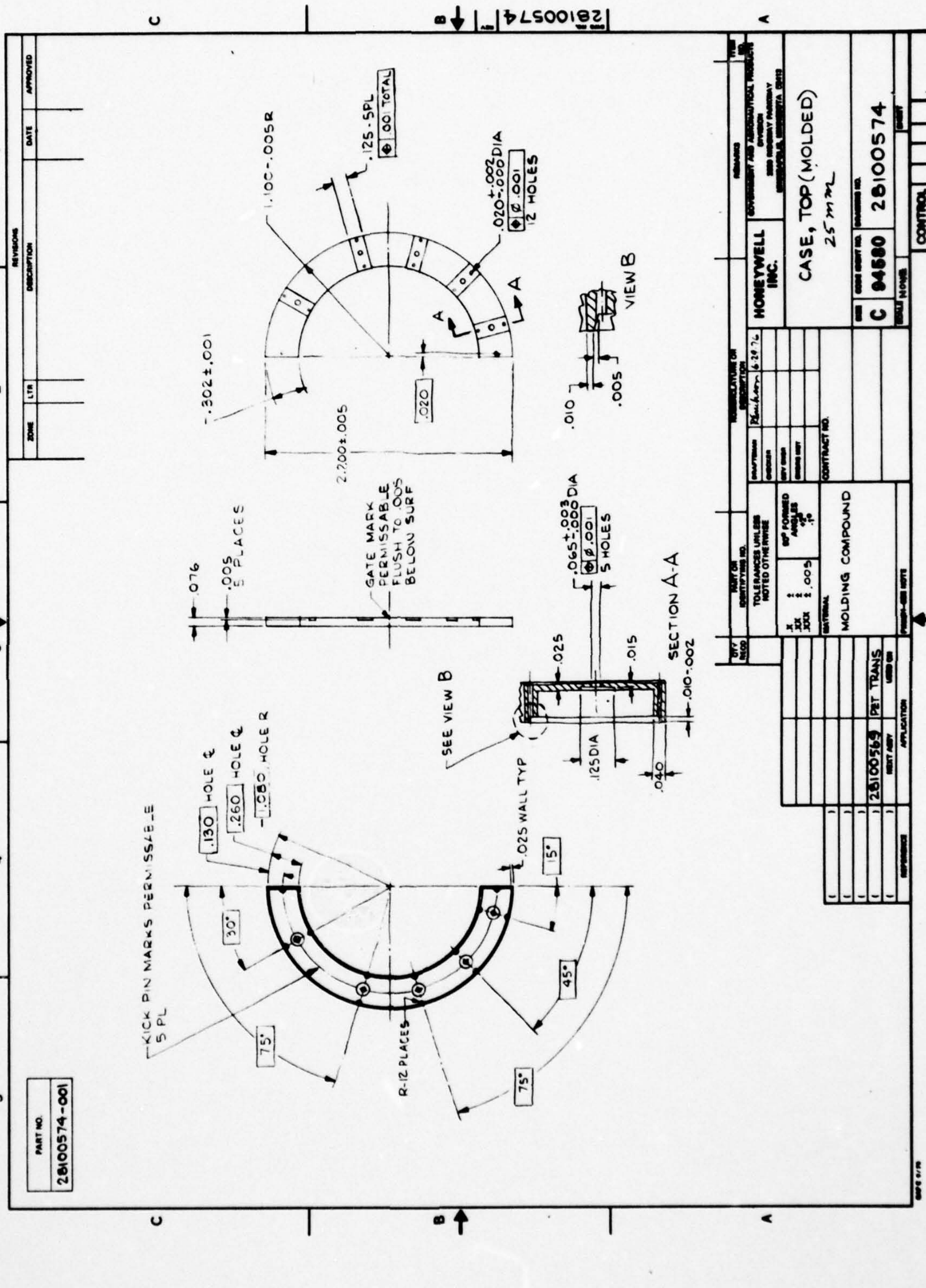


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
PART NO.
28100571-001
.010±.001
ELECTRODE PATTERN THIS SIDE ONLY
.080±.010
1.000
.435±.010 2 PL
.010±.010 UNPLATED AREA 2 PLACES
.865±.001 R
1.050±.001 R
ELECTRODE PATTERN BOTH SIDES - 2 PL
TOLERANCES UNLESS NOTED OTHERWISE
.XXX ±.005
28100561
PET TRANS
NEXT ASSY
USED ON
APPLICATION
HONEYWELL INC.
ELEMENT, PIEZOELECTRIC
C
94580
28100571
CONTROL



HONEYWELL INC.
SHORTING BAR
B
94580
28100573
CONTROL
PART NO.
28100573-001
28100575
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
TOLERANCES UNLESS NOTED OTHERWISE
MATERIAL
.005 THK
KOVAR
FINISH-SEE NOTE 1
28100569
PZT TRANS
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO
4 HOLES
.015
.040
.057
.130
.260
.296
.060±.002
.802 R
1- .00003-24 K GOLD OVER
.001 COPPER


PART NO.
28100569-001
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
SECTION A-A
TYPICAL OF 5
.040±.010
7 PL
.020±.001 DIA
3 HOLES OFF CENTER
V3, V12 & P-
.020±.001 DIA
3 HOLES OFF
CENTER
P-
NOTES:
1 - TRANSFER TAPE
2 - SILASTIC PRIMER
3 - SILASTIC PAD
4 - MARKING APPROX .12 HIGH
5 - USE SHORTING BAR 28100573-001
TO LOCATE DRILLED HOLES
5 28100572-001 TERMINAL 3
5 28100573-001 SHORTING BAR 2
1 28100574-001 CASE 1
QTY REQD | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | REMARKS | ITEM NO.
TOLERANCES UNLESS NOTED OTHERWISE
90° FORMED ANGLES
DRAFTSMAN
CHECKER
DEV ENGR
ENGRG MGT
CONTRACT NO.
C9-5-N0005-05-C9-CA
HONEYWELL INC.
GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
2600 RIDGWAY PARKWAY
MINNEAPOLIS, MINNESOTA 55413
CASE, TOP
(25MM)
SIZE C
CODE IDENT NO. 94580
DRAWING NO. 28100569
28100569 PZT TRANS
NEXT ASSY USED ON
REFERENCE APPLICATION
MATERIAL
FINISH-SEE NOTE
SCALE SHEET
CONTROL


PART NO.
28100574-001
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
KICK PIN MARKS PERMISSABLE
5 PL
.130 HOLE ℄
.260 HOLE ℄
.080 HOLE R
.025 WALL TYP
30°
75°
45°
15°
75°
R-12 PLACES
SEE VIEW B
.125 DIA
.040
.025
.015
.010-.002
SECTION A-A
.065+.003 -.000 DIA
Ø.001
5 HOLES
.076
.005
5 PLACES
GATE MARK PERMISSABLE FLUSH TO .005 BELOW SURF
2.200±.005
.302±.001
.020
1.100-.005R
.125 5PL
.001 TOTAL
.020+.002 -.000 DIA
Ø.001
12 HOLES
VIEW B
.010
.005
28100574
TOLERANCES UNLESS NOTED OTHERWISE
MOLDING COMPOUND
28100569
PET TRANS
NEXT ASSY
USED ON
APPLICATION
HONEYWELL INC.
CASE, TOP (MOLDED)
25 mm
C
94580
28100574
CONTROL

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